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BLOSSOM-BLIGHT OF MANGOS IN THE PHILIPPINES

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SEVENTEEN PLATES

INTRODUCTION

Blossom-blight of the mango, *Mangifera indica* Linnæus, caused by the hoppers *Idiocerus clypealis* Léthierry and *I. niveosparsus* Léthierry, is so far the most destructive and most common pest of mangos known in the Philippines. It has been observed to attack all the different varieties of mango; such as, carabao, pico, señora, and many other unidentified hybrids. All of these varieties seem to be equally susceptible to the infestation under more or less identical conditions. The pahutan, *Mangifera altissima* Blanco, which is taken by many people as a variety of mango, is attacked by the same pest but, for some reason or other, it does not seem to suffer therefrom no matter how severe the infestation may be.

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This pest has been reported in Batangas, Cavite, Laguna, Rizal, Bulacan, Bataan, Zambales, Pampanga, Tarlac, Nueva Ecija, and Pangasinan Provinces. While the northern provinces of Luzon, the Bicol Provinces, the Visayan Islands, and Mindanao and Sulu Archipelago have not been surveyed, it seems highly probable that the same pest will be found in some if not all of those localities judging from its severity and distribution in and around Manila. Whether or not it is indigenous to the Islands is unknown.

There is no doubt that it is gaining ground and becoming more serious, especially in Bulacan, Cavite, and Rizal Provinces. Growers are more or less unanimous in the belief that ten or twenty years ago this pest was not as severe as it is now. The data in Table 1, from an actual survey conducted by the writers in May, 1932, serve to show the seriousness of the situation.

TABLE 1.—*Total percentage of infestation by the blossom-blight hoppers, Idiocerus clypealis and I. niveosparsus, in each province surveyed.*

Province.[a]	Trees examined.	Hoppers.	Infested trees.			
			Light.	Moderate.	Severe.	Total.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Cavite	131	I. C.	28.25	17.56	54.19	100.00
		I. N.	8.39	8.39	3.05	19.84
Bulacan	143	I. C.	20.28	22.37	53.14	95.70
		I. N.	20.97	8.39	4.19	35.56
Rizal	1,556	I. C.	37.01	34.64	21.84	93.50
		I. N.	49.74	23.20	3.85	76.80
Average		I. C.	35.08	32.45	26.61	94.15
		I. N.	44.42	20.76	3.93	69.12

[a] The following municipalities were covered by this survey: Cavite Province: Bacoor, Imus, Dasmariñas, Noveleta, Caridad, San Roque. Bulacan Province: Meycauayan, Marilao, Bigaa, Guiguinto, Quingua, Pulilan, Baliuag. Rizal Province: Las Piñas, Muntinlupa.

It may be seen from Table 1 that of 1,830 trees examined, 94.15 per cent showed infestation by *Idiocerus clypealis* and 69.12 per cent by *I. niveosparsus,* indicating that the former is preponderant. Disregarding the infestation due to *I. niveosparsus,* which is already included in the figures for *I. clypealis,* and considering that four-fifths of the flowers with the average infestation of 94.15 per cent were totally damaged by the hoppers while the rest survived, which is a very conservative estimate based on actual observations in the field, the total mango crop actually harvested in the three provinces covered by the survey represented but 24.68 per cent of what it should really have been if there were no infestation at all.

In Manila and suburbs like Santa Mesa and Santa Ana there was a moderate to severe infestation by the hoppers in February, 1932, causing a total destruction of the inflorescences in many cases. From all indications, however, the greatest damage done to the mango crop in that season was in Pasay and Novaliches, Rizal Province. Practically all of the trees, about two hundred in the municipality of Pasay, bloomed profusely in January, 1932; but owing to the devastation caused by the hoppers, particularly *I. niveosparsus*, no mango crop to speak of was harvested the following summer. Similarly, it is said that in the hacienda of Dr. N. Jacinto in Novaliches one hundred trees, which were smudged[2] in November and December, 1931, all bloomed profusely, but the crop was practically a total loss owing to the ravages of this pest.

Again, it was learned from the mango growers in Muntinlupa, Rizal Province, that sometime in 1910, prior to the outbreak of this pest, their mango trees generally were so heavily laden with fruits that there were times when they could not pick them all. But now the crop they generally get does not even suffice to cover the expenses incurred in smudging. The existing condition is so disheartening that, unless something is done by the Government to aid the growers, the total yearly output of mangos may suffer a further decrease.

Numerous inquiries from growers all over the mango-producing sections where the hoppers are present seem to indicate that the pest really is an all-important problem and warrants a more careful and exhaustive study than it has been accorded heretofore. The life history and habits of the hoppers need to be investigated more thoroughly; for, unless these are clearly understood, control measures can only be empirical.

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[2] "Smudging" or "smoking" is a process of forcing the mango to flower early or before the usual season, by burning trash with green weeds or green leaves and branches of shrubs or trees under the mango trees generally during the whole day for from seven to ten or more consecutive days. This is a common practice in nearly all the mango-growing sections of the Archipelago.

All of this, together with the great economic importance of the pest, considering that the mango is admittedly the premier dessert fruit in the Philippines, made a new investigation of this problem necessary. This paper covers mainly the results of the spraying experiments that have been finished so far, together with an enumeration of other miscellaneous factors that were observed to be more or less intimately associated with the reduction of mango yield. Some new facts have been discovered that give rise to advice which, if followed, would help the growers save much of their mango crop.

HISTORICAL REVIEW

As far back as 1845 Blanco,(1) in his Flora de Filipinas, referred to mango failure. However, he did not state the cause of such failure, although the common belief among the natives, that when rain is abundant the mango crop is poor and the rice crop plentiful, was viewed by him with approval. It was not explained, however, how rain was inimical to the mango. It is possible that the occurrence of the blossom-blight pest dates back as far as the early Spanish régime.

The available literature on the subject indicates that little work has been done on this pest in the Philippines. It was first reported by Wester(2) as causing damage to the mango crop in Bataan and Cavite Provinces in April, 1911. In 1924, the Bureau of Agriculture(3) reported the great damage done to the mango blossoms in the Islands.

Although apparently present and very destructive before, no serious attention was paid to it until March, 1930, when Palo(4) found the same pest to have greatly contributed in causing enormous losses to the crops in practically all the mango-growing sections around Manila, particularly in Bulacan and Rizal Provinces. He also found other factors contributing to the reduction of the mango crop, such as the anthracnose caused by the *Gloeosporium* stage of *Glomerella cingulata* (Stonem.) S. and v. S., and the tip-borer, caused by *Chlumetia transversa* Walker. In his spraying experiments in 1931, he used Bordeaux-nicotine-lead arsenate combination in addition to nicotine-soap, and showed that this treatment could increase the yield of the treated trees many times over that of the control.

In 1930, Ramachandra Rao(5) reported that the hoppers with mildews and other insect pests were reducing the mango crop in southern India. He found *Idiocerus niveosparsus* to be more destructive than *I. clypealis*. The first attempt he made at spraying to control this pest was in Chittoor District in 1913. A preliminary spray with Bordeaux mixture followed by fish-oil-resin soap was found by him to be effective in minimizing the ravages of the pests.

Wagle(6) reported in May, 1928, that the hopper *Idiocerus niveosparsus* and a mildew of the genus *Erysiphe* were partly responsible for the shedding of mango flowers and fruits in Ratnagiri and Thana Bombay Presidency, India. He found Bordeaux-mixture spray effective for the mildew, increasing the percentage of maturing fruits by 21 per cent in one instance and by 230 per cent in another. In the presence of hoppers he found that spraying with fish-oil-soap solution increased the yield of fruits by 62 per cent. A combination of the two sprays was not effective even against hoppers.

DESCRIPTION OF THE MANGO FLOWER

The flower of the mango has been the subject of many investigations, and several descriptions of it in detail were published recently. The present description deals only with its growth in relation to the period of hopper infestation and the percentage of perfect flowers, which many believe has a direct correlation with production. The two leading local varieties, the carabao and the pico, were used for this determination.

The mango inflorescence contains both hermaphrodite, or perfect, flowers and staminate, or male, flowers. Popenoe(7) states that each panicle carries from 200 or 300 to more than 4,000 flowers, of which only 2 to 3 per cent are perfect in some varieties, and as many as 60 to 75 per cent in others. He found the Philippine varieties to have in general more perfect flowers than staminate flowers.

Wagle(6) has found that the percentage of perfect flowers varies with the different flower flushes from the same tree, with the flowers from the same tree at different seasons, and with the flowers from different varieties, but not with flowers from individual trees of the same variety. This variation, if true, might have been the reason why the percentage of perfect flowers of carabao and pico varieties, while relatively high, as shown in Table 2, was found not to exceed 50 per cent in either case, which is contrary to the report of Popenoe.(7) Table 2 represents a summary of the study made on twenty trees on the basis of five panicles per tree. This was conducted in February, 1932, in Bayanan, Muntinlupa, Rizal Province.

TABLE 2.—*Percentage of perfect flowers of carabao and pico varieties.*

Carabao.		Pico.	
Tree No.	Perfect flowers.	Tree No.	Perfect flowers.
	Per cent.		*Per cent.*
1	54.5	12	30.0
2	43.0	13	24.7
21	41.0	15	26.6
24	47.4	22	26.6
27	47.7	25	19.4
28	46.3	30	30.3
40	41.1	34	50.0
44	48.0	36	13.7
55	40.0	41	22.0
56	49.0	45	24.4
70	48.0	52	23.0
75	39.3	60	13.0
Average	45.2	Average	25.3

As shown in Table 2, the carabao variety has on the average 45.2 per cent perfect flowers, and the pico variety only 25.3 per cent. Whether or not carabao is the better yielder of the two owing to its higher percentage of perfect flowers, will be discussed under the spraying experiments.

It was thought necessary to have an idea of the relative average daily growth of the mango inflorescence in relation to hopper infestation and its control. One healthy-looking carabao tree about 40 years old, with the inflorescence buds just emerging from their protective covering, was selected for this purpose. Twenty of such buds were tagged and the growth of each was measured every other day until the twenty-third day when all of them ceased to grow. The results of these observations are given in Table 3.

It may be seen from Table 3 that the average daily growth of carabao mango inflorescence gradually increases from the day the panicle emerges from the bud to about the tenth or eleventh day, when it reaches the maximum, and then gradually decreases, until about the twenty-first day, when all the flower buds have expanded and full development has been attained. The flower buds on the basal portion are generally the first to open, beginning the thirteenth day or thereabout. By the time the flowers on the apices of the lateral branches and spikelets have completely opened and the panicle has ceased to grow, the staminate and other unfertilized flowers on the basal portion of the inflorescence begin to wither and fall, while the fertilized perfect flowers are just beginning to set fruits.

TABLE 3.—*Relative average growth of carabao mango inflorescence.*

Date observed.	Average of 20 panicles.	
	Length.	Growth.
1932	*cm.*	*cm.*
March 31	1.0	
April 2	1.7	0.7
April 4	3.5	1.8
April 6	7.3	3.8
April 8	14.4	7.1
April 10	22.9	8.5
April 12	28.4	5.5
April 14	31.9	3.5
April 16	32.8	0.9
April 18	33.4	0.6
April 20	33.6	0.2
April 22	33.6	Nil.
April 24	33.6	Nil.

DESCRIPTION OF THE BLOSSOM-BLIGHT

As the name implies, mango "blossom-blight" is the blighting or withering of the inflorescences of mangos, before or after the opening of the flower buds, resulting from the infestation by the two species of mango leaf-hoppers, *Idiocerus clypealis* and *I. niveosparsus.*

The name "blossom-blight" was chosen for this pest to distinguish it from other common names like mango-blight, mildew, and anthracnose caused by the *Gloeosporium* stage of *Glomerella cingulata* (Stonem.) S. and v. S. The term "mango-hoppers," as used by Ramachandra Rao(5) and Palo(4) for the same pest, sounds rather ambiguous and misleading in as much as in the Philippines there are five or six kinds of hoppers feeding on mango, only two of which are responsible, either singly or jointly, for the destruction of the flowers in so far as the writers' observations and findings are concerned. Therefore, naming this pest simply "mango hopper" may include all of them. On the other hand, "blossom-blight" stands for one definite object, denoting a characteristic blighting of the blossom, hence the name (Plate 2, figs. 1 and 2).

The mango blossom-blight may manifest itself in about ten to twenty days or more from the date of the outbreak, depending on the volume of infestation and age of the inflorescence when the eggs are laid. The adult hoppers begin to lay eggs soon after the inflorescence buds have appeared and the tender panicles have grown to a length of 2 to 4 centimeters. Egg punctures may be noted in the flower stems and buds immediately after the occurrence of the first infestation. Early outbreak coupled with profuse egg-laying of the hoppers may cause the inflorescence to wither and drop before the opening of the flowers is completed (Plate 3, figs. 1 and 2). When this occurs the crop is doomed (Plate 4, fig. 1). There are cases, however, where the infestation is neither as early nor as heavy as this, thereby allowing some fruits to set and develop to maturity (Plate 4, fig. 2).

When the eggs hatch the young ones feed on the inflorescence by piercing the tissues with their proboscis and sucking the juice from them. In severe outbreaks the nymphs may occur in hundreds on a single inflorescence and cause blighting of the flowers after a few days. When the infested inflorescence is agitated violently the nymphs on the flowers may be seen moving downward to hide on the lower parts of the twigs and the nether sides of the leaves (Plate 5, figs. 1 and 2).

The hoppers may damage the mango crop in two distinct ways: first, owing to the heaviness of egg-laying, physical injury is inflicted on the flower stems as well as on the individual flower buds, thereby causing them to wither and drop; and second, the nymphs that hatch in large numbers crowd together among the florets and, with their proboscis, pierce the tissues of the flower stems and draw the sap. Most of the sap thus sucked is excreted after a certain amount of digestion as droplets of sticky, sweetish fluid commonly known as "honey-dew." In severe cases of infestation not only the inflorescences, leaves, and branches of the tree, but also the plants and the ground below may be found covered with a fairly thick incrustation of this fluid. When the weather is dry the honey-dew dries into a transparent, shiny, yellow deposit, and if there be some rainfall or even a heavy fall of dew, it serves as a rich medium for the growth of sooty mold, *Chaetothyrium mangiferae* Mendoza, which is more or less constantly associated with blossom-blight.

Abundant growth of this mold on a mango tree may, therefore, be an indication that there had been a severe hopper infestation on that tree.

DESCRIPTION OF THE HOPPERS

SYSTEMATIC POSITION

Palo(4) reported that Dr. L. B. Uichanco, professor of entomology in the College of Agriculture, University of the Philippines, identified these two species of hoppers causing mango blossom-blight, as follows:

Order Homoptera; family Cicadellidæ; subfamily Bythoscopenæ.

1. *Idiocerus niveosparsus* Léthierry. This is the large brown species, about 4.5 mm long.
2. *Idiocerus clypealis* Léthierry. A much smaller species, only about 3.5 mm long, ground color, light greenish.

NAMES OF THE INSECTS

The large species is *Idiocerus niveosparsus* Léthierry, and the small species *I. clypealis* Léthierry. There is no local name that fittingly describes these insects, although in Tagalog regions they are sometimes called "kuliglig-maliit," or "hanip." "Hanip" is more commonly used because the newly hatched *Idiocerus clypealis*, which is the commoner of the two species, looks much like a mite. "Hanip" is the Tagalog word for mite.

LIFE HISTORY

The life history of the two species of mango blossom-blight hoppers was studied in Muntinlupa, Rizal Province, from April to May, 1932. This experiment was carried out in the following manner:

Twelve uniform about-to-open inflorescence buds were selected and each was inclosed in a celluloid cylinder 52 centimeters long and 22 centimeters in diameter, with cheese-cloth covers at both ends, taking the necessary precaution so that no insects, to begin with, were inclosed in the cages (Plate 6, figs. 1 and 2). After six days when the inflorescences had grown to a certain length a pregnant hopper (*Idiocerus clypealis*), with a large protruding abdomen, was introduced in each of the twelve cylinders and allowed to remain for twenty-four hours during which period oviposition was observed. At the termination of twenty-four hours all of the hoppers were released. After the fourth day, upon agitating the panicles, the young ones began to come out as tiny ivory-yellow nymphs measuring a fraction of a millimeter. Daily observations were continued, the period of each molt being noted. After nine to ten days the nymphs were found to have molted four times, eventually becoming adults (Plate 1, figs. 1 to 6).

The same procedure was followed in studying the second species, *Idiocerus niveosparsus,* which was found to have five nymphal stages (Plate 1, figs. 8 to 14). The results of these two series are given in Table 4.

TABLE 4.—*Life history of the mango blossom-blight hoppers.*

Species.	Incubation period.	Stage.						Total span from egg to adult.
		First.	Second.	Third.	Fourth.	Fifth.	Nymphal.	
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
Idiocerus clypealis	4.5	1.9	2.0	2.2	3.5	--------	9.6	14.1
Idiocerus niveosparsus	4.1	1.1	1.2	1.2	1.7	2.2	7.4	11.5

When the tests were conducted on detached inflorescences suspended in vials with cheese-cloth covers and water to keep the flowers fresh under laboratory conditions, the life cycle was lengthened by several hours. This would seem to indicate that the supply of food as well as the environmental conditions; that is, temperature and moisture, play their rôles in the life history and habits of these hoppers.

THE NYMPHS

Idiocerus clypealis.—As may be seen from Table 4 there are but four nymphal stages credited to this species. The first stage measures about 0.75 millimeter long, and is ivory-yellow turning cream-buff, then vinaceous-fawn.[3] Some nymphs may be olive-ocher or bluish black with a cream stripe when they pass to the second and third stages. The nymph increases in size gradually as it grows from one stage to the next until it reaches about 3.5 millimeters in length when it molts for the last time and becomes an adult (Plate 1, figs. 2 to 5). The time interval of molting seems to increase as the nymph grows older. On the average the nymphal stage covers about nine days fourteen hours.

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[3] The colors indicated here and elsewhere in this paper are those of Ridgway's Color Standards and Color Nomenclature. Washington (1912).

It may be of interest to mention that the exuviæ of the first three nymphal stages may be found among the flowers, while the fourth and last exuvia may be seen stuck in the natural position on the lower surface of the leaves below the panicle. If there are new leaf flushes on the tree practically all of the fourth exuviæ will be found there, owing perhaps to the fact that the last nymphal stage of this hopper seems to prefer seclusion under those leaves (Plate 7, figs. 1 and 2).

Idiocerus niveosparsus.—Unlike the first species there are five nymphal stages credited to *Idiocerus niveosparsus.* Ramachandra Rao(5) and Wagle,(6) on the other hand, reported but four for both.

The first stage measures about 1 millimeter long, and is pale sky gray turning vinaceous-lilac, then brownish drab to dusky drab. The eyes are neutral red at first, turning taupe brown later. The nymph gradually increases in size as it grows older from one stage to the next until it reaches 4.5 millimeters long when it molts for the fifth time to become an adult (Plate 1, figs. 9 to 13). As in *Idiocerus clypealis* the time interval of molting seems to increase as the nymph grows older, although it is considerably shorter in this case. On the average the nymphal stage covers about seven days ten hours, which is more than two days shorter than that of *Idiocerus clypealis.*

The exuviæ of this species may be found with difficulty, generally among the flowers and occasionally on the lower surface of the leaves. Unlike *Idiocerus clypealis* the last nymphal stage of this species does not seem to select a special place in which to deposit the exuviæ; hence, the difficulty in locating them.

THE ADULTS

The adults of both species are wedge-shaped. They can move about and fly from flower to flower, leaf to leaf, or even tree to tree. They like cool, sheltered places, hence they are more abundant in thick growths with heavy shade than in open places. Like the nymph, the adult has a proboscis with which it sucks plant juice; which, after some digestion, it excretes in droplets of sweet sticky fluid commonly known as "honey-dew." Both species may be found together in the same inflorescence or in the same tree, with *Idiocerus clypealis* generally preponderant at the beginning, but gradually losing ground until eventually *I. niveosparsus* gains the upper hand. This eventual preponderance of *I. niveosparsus* when both species occur in a tree, is due, perhaps, not to the latter's physical superiority over the former, but to the fact that as soon as the flowers begin to wither *I. clypealis,* unlike *I. niveosparsus,* cannot lay its eggs any more, hence it moves to adjacent trees in search of fresh materials. Upon approaching a tree with many adult hoppers one will hear a cricking noise caused by their flight from leaf to leaf.

Idiocerus clypealis.—The adults of this species are cinnamon-drab with white spots just behind the head. The female is 4 millimeters and the male 3.8 millimeters long (Plate 1, fig. 6).

Unlike the other species *Idiocerus clypealis* lays its eggs in the flower buds only (Plate 1, fig. 1) and has not been observed to copulate after the blooming season is over even in the presence of suitable feed like the flower flushes produced by smudging. The reason for this is not known.

Idiocerus niveosparsus.—The adults are dusky-drab with light stripes on the wings. The female is a little larger than the male, measuring 5⅙ millimeters in length, while the male is 5 millimeters (Plate 1, fig. 14).

During the mango flowering season this species also feeds on the sap of the inflorescence and lays its eggs in the axis of the flower heads, in the flower buds and in the flower stems (Plate 1, fig. 8). During the offseason it generally feeds on the new leaf flushes and lays its eggs in the tender midribs of the young leaves, usually on the lower side.

THE EGGS

Idiocerus clypealis.—The eggs of this species are usually in pairs, cream colored, cigar-shaped, tapering at one end and slightly round at the other (Plate 1, fig. 1). They are about 0.75 millimeter long and 0.1 millimeter thick. They hatch in about four and one-half days, so that, with the nymphal stage being completed in about nine and one-half days, the whole life history from the laying of the eggs to the emergence of the adult hopper is about fourteen days.

Idiocerus niveosparsus.—The eggs of this species are ivory-cream, cigar-shaped, tapering at one end and slightly round at the other (Plate 1, fig. 8). They are about 1.2 millimeters long and 0.3 millimeter thick. To the tapering end is attached a white woolly covering perhaps to protect the eggs from desiccation, this end being partly exposed. They hatch in a little over four days so that, with the nymphal stage being completed in about seven and one-half days, the whole life history from the laying of the egg to the emergence of the adult hopper is completed in about eleven and one-half days, or two and one-half days less than that of *I. clypealis.*

SEASONAL ACTIVITIES

Both species of mango-blight hoppers, *Idiocerus clypealis* and *I. niveosparsus,* seem to be most active during the flowering season; that is beginning December or even as early as October and November, if the trees are smudged, until April when the flowers begin to wither. During these months the hoppers feed on and lay eggs in the mango inflorescences. As soon as the mango flowers wither and fall the hoppers are less conspicuous. However, examination of the mango trees will reveal the hoppers although they are fewer in number. This has been shown by the survey made in Pasay, Rizal Province, July 15 and 16, 1932, the results of which are given in Table 5.

TABLE 5.—*The relative abundance of the blossom-blight hoppers, Idiocerus clypealis and I. niveosparsus, on the carabao and pico varieties of mango during the season when there are neither flowers nor fruits. (Surveyed July 15 and 16, 1932, at Pasay, Rizal Province.)*

Trees examined.	Hoppers.	Infested trees.			Total.
		Few.	Moderate.	Abundant.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Carabao-170	I. C.	38.23	59.41	1.17	98.82
	I. N.	32.94	0	0	32.94
Pico-205	I. C.	44.39	53.66	1.95	100.00
	I. N.	42.43	0	0	42.43

It seems that these hoppers can live on the mango leaves in the absence of the flowers. Only *Idiocerus niveosparsus,* however, was found copulating and laying eggs during the off-season, although somewhat limited in extent. The eggs are laid in the midribs of tender leaves, generally on the lower surface.

Now comes the question as to whether or not both species can live on plants other than the mangos. A search for such plants around Muntinlupa from February to May, 1932, ended in vain. It was not until June, 1932, after all the mango flowers had withered and dried, that some of such plants appeared suspicious. Uphill at the Hacienda Madrigal in Muntinlupa the adults of *Idiocerus clypealis* were found resting on the leaves of madre cacao, *Gliricidia sepium* (Jacq.) Steud.; sineguelas, *Spondias purpurea* Linn.; and guava, *Psidium guajava* Linn. In Pasay, as shown by the survey conducted July 15 and 16, 1932, adults of *Idiocerus clypealis* were found on fourteen plants besides the mangos, as follows:

Breadfruit; *Artocarpus communis* Forst.
Jackfruit; *Artocarpus integra* (Thunb.) Merr.
Achuete; *Bixa orellana* Linn.
Tampoy; *Eugenia jambos* Linn.
Chinese litchi; *Litchi sinensis* Sonn.
Guanabano; *Anona muricata* Linn.
Gumamela; *Hibiscus rosasinensis* Linn.
Sampaguita; *Jasminum sambac* (Linn.) Ait.
Alagao; *Premna odorata* Blanco.
Anonang; *Cordia dichotoma* Forst. f.
Balimbing; *Averrhoa carambola* Linn.
Calamondin; *Citrus mitis* Blanco.
Santol; *Sandoricum koetjape* (Burm. f.) Merr.
Lucban; *Citrus decumana* Murr.

The following experiment was laid out to determine whether or not the plants above mentioned serve as intermediary hosts to *Idiocerus clypealis:* Nineteen cages of celluloid cylinders with cheesecloth covers at both ends, similar to those employed in the study of the life history of the hoppers, were fixed. The first cage was suspended under the shade of a mango tree after fifty adults of *I. clypealis* had been introduced into it without anything to eat, while the remaining eighteen were set out and distributed, one by one, under shade among the same number of plants above named including mango, each inclosing the same number of adults with a twig of each of the corresponding plants undetached for the hoppers to feed on. Daily observation was made for a month, and the daily rate of mortality in each cage was noted. Table 6 gives the results obtained.

The results shown in Table 6 seem to indicate that *Idiocerus clypealis* cannot live over three days if left alone with nothing to eat; that it can partly live on various plants which apparently serve as intermediary hosts; and that if necessary it can feed on almost any kind of plant and live for some time, depending on the suitability of the feed. This peculiarity of *I. clypealis,* which is not found in *I. niveosparsus,* may serve as a working hypothesis for explaining why the former seems to outlive the latter.

PARASITISM

Like most other insect pests, the mango blossom-blight hoppers have some natural enemies of their own. The adults of *Idiocerus clypealis* have been observed to be affected by a fungous parasite, which is being studied. This fungus seems to be capable of attacking and killing the insects, pasting them firmly with the brown, matted, mycelialike filaments on the lower surface of the mango leaves as well as on the leaves of the intermediary hosts (Plate 8, figs. 1 and 2). This is, by the way, further strong evidence showing that when there are no mango flowers the hoppers live, at least partly, on other host plants. However, it has not been observed to attack the nymphs of either species or the adults of *I. niveosparsus.* Circumstantial evidence seems to indicate that this fungus, like most other fungi, is not favored by dry weather and, hence, does not seem to be active during summer. This may explain why no infections were found during the blooming season.

Subramaniam(8) has found the mango leaf-hoppers (*Idiocerus* spp.) in India to be parasitized by a pipunculid fly, *Pipunculus annulifemur* Brun.; a stylopid parasite, *Pyrilloxenos compactus* Pierce; an epipyropid moth, *Epipyrops fuliginosa* Tams.; and a dryinid wasp.

There are more than twenty predators[4] feeding wholly or partially on the nymphs. The following are some of those that have been observed actually feeding on the nymphs and eggs of the mango blossom-blight hoppers: The larvæ of three lady-bird beetles, *Nida billardieri* Crorch, *Epilachna punctata* Fabr., and *Coccinilla octamaculata* Fabr.; a medium-sized black ant, *Dolichoderus bituberculatus* Magr.; a medium-sized brown ant, *Tapinoma melanocephalum* Fabr.; a tiny brown ant, *Monomorium destructor* Jerdon; and a score or more kinds of spiders. The last-named ant was observed especially active in burrowing and eating the eggs from egg punctures of *Idiocerus niveosparsus.*

The importance of these predators and parasites, particularly the fungous parasite, as biological controls of the mango blossom-blight hoppers should be investigated.

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[4] Identified by Messrs. Fidel del Rosario and Gervasio Bellosillo, assistant systematic entomologists of the Bureau of Science.

TABLE 6.—*Percentage mortality of adult Idiocerus clypealis in cages with and without feed to live on, based on fifty individuals.*

Food plant.	July, 1932.																
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1. None	0	14	60	100													
2. Mango; *Mangifera indica* Linn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Madre cacao; *Gliricidia sepium* (Jacq.) Steud	0	0	20	40	50	58	66	66	72	80	88	90	96	96	100		
4. Sineguelas; *Spondias purpurea* Linn	0	0	22	42	56	68	70	74	82	90	90	94	100				
5. Guava; *Psidium guajava* Linn	0	0	4	10	10	14	34	54	66	100							
6. Breadfruit; *Artocarpus communis* Forst.	0	0	0	0	0	0	0	0	4	8	20	40	60	84	88	88	92
7. Jackfruit; *Artocarpus integra* (Thunb.) Merr	0	0	0	0	6	10	30	30	42	50	56	64	74	78	92	94	96
8. Achuete; *Bixa orellana* Linn	0	4	4	4	52	52	56	58	64	72	73	78	86	100			
9. Tampoy; *Eugenia jambos* Linn	0	0	0	0	20	28	36	42	54	68	68	72	78	80	80	84	84
10. Chinese litchi; *Litchi sinensis* Sonn	0	0	0	0	0	0	8	18	22	30	34	38	44	46	50	64	72
11. Guanabano; *Anona muricata* Linn	0	0	0	0	14	34	34	38	42	68	80	82	84	88	92	94	94
12. Gumamela; *Hibiscus rosasinensis* Linn	0	0	0	0	0	20	28	34	38	46	64	70	78	82	84	88	92
13. Sampaguita; *Jasminum sambac* (Linn.) Ait	0	0	24	26	32	38	46	48	56	62	68	76	86	94	100		
14. Alagao; *Premna odorata* Blanco	0	0	0	16	24	34	40	46	50	70	80	84	88	90	92	96	100
15. Anonang; *Cordia dichotoma* Forst. f	0	0	0	0	0	0	4	8	20	40	60	84	88	88	92	94	98
16. Balimbing; *Averrhoa carambola* Linn	0	4	6	10	26	42	60	64	76	88	92	96	100				
17. Calamondin; *Citrus mitis* Blanco	0	22	26	30	44	64	74	82	88	90	98	100					
18. Santol; *Sandoricum koetjape* (Burm. f.) Merr	0	6	8	12	18	28	32	36	46	72	88	90	92	100			
19. Lucban; *Citrus decumana* Murr	0	18	26	40	68	78	82	86	92	96	96	98	100				

Food plant.	August, 1932.												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1. None													
2. Mango; *Mangifera indica* Linn.	4	8	14	14	14	14	14	14	20	24	32	32	40
3. Madre cacao; *Gliricidia sepium* (Jacq.) Steud													
4. Sineguelas; *Spondias purpurea* Linn.													
5. Guava; *Psidium guajava* Linn.													
6. Breadfruit; *Artocarpus communis* Forst.	92	92	96	100									
7. Jackfruit; *Artocarpus integra* (Thunb.) Merr	96	100											
8. Achuete; *Bixa orellana* Linn.													
9. Tampoy; *Eugenia jambos* Linn.	88	96	100										
10. Chinese litchi; *Litchi sinensis* Sonn.	74	80	92	94	98	100							
11. Guanabano; *Anona muricata* Linn.	98	100											
12. Gumamela; *Hibiscus rosasinensis* Linn.	92	92	100										
13. Sampaguita; *Jasminum sambac* (Linn.) Ait.													
14. Alagao; *Premna odorata* Blanco.													
15. Anonang; *Cordia dichotoma* Forst. f	98	100											
16. Balimbing; *Averrhoa carambola* Linn.													
17. Calamondin; *Citrus mitis* Blanco.													
18. Santol; *Sandoricum koetjape* (Burm. f.) Merr													
19. Lucban; *Citrus decumana* Murr.													

INFESTATION EXPERIMENT

To ascertain the relative destructiveness of the two species of mango hoppers, *Idiocerus clypealis* and *I. niveosparsus*, the following experiment was conducted in April, 1932, in Muntinlupa, Rizal Province, Luzon.

Forty uniform about-to-open inflorescence buds on a pico mango tree were caged each in a celluloid cylinder 52 centimeters long and 22 centimeters in diameter with cheese-cloth covers at both ends, taking precautions that no insects, to start with, were present in the inclosure. These cages were grouped into five series of eight cylinders each. On the fifth day, or four days after the opening of the inflorescence buds, 17 pregnant *Idiocerus clypealis* in batches of 2, 5, and 10 were introduced each in the first three cylinders Nos. 1, 3, and 5 of the first series; to the next three cylinders Nos. 2, 4, and 6 the same number of pregnant *I. niveosparsus* were introduced in the same batches of 2, 5, and 10, while the remaining two cylinders Nos. 7 and 8 were not infested, as check. The same procedure was followed in series 2, 3, 4, and 5 when the inflorescences were at the ages of 6, 8, 10, and 15 days, respectively. These five series were duplicated, using a carabao tree instead.

After a month the whole series was examined; the results are given in Table 7.

Table 7 shows interesting results. Series 1: At the age of four days and with a length of 2 to 4 centimeters the inflorescence buds readily succumbed to the infestation by both species of hoppers, all of them having withered before the flowers completed opening.

Series 2: All excepting one, which had but two *Idiocerus clypealis*, were totally damaged.

Series 3: All that had infestation by *Idiocerus niveosparsus* were totally damaged, while those that had but two *I. clypealis* were slightly damaged; those that had five were severely damaged, and those that had ten were completely damaged (Plate 9, figs. 1 and 2).

Series 4: All those infested by *Idiocerus niveosparsus* were totally damaged, except one that had but two, which were severely damaged. Those that had two, five, and ten *I. clypealis* were very slightly, slightly, and severely damaged, respectively.

Series 5: Only those that had ten *Idiocerus niveosparsus* were completely damaged, and those that had five and two were

TABLE 7.—*Time and volume of hopper infestation in relation to extent of damage caused thereby.*[b]

Series.	Cage No.	Inflorescence.		Pregnant hoppers inclosed.	Damage done to the inflorescence by—	
		Age.	Length.		*I. clypealis.*	*I. niveosparsus.*
		Days.	*cm.*			
First	1- 2	4	2- 4	2	Total	Total.
Do	3- 4	4	2- 4	5	do	Do.
Do	5- 6	4	2- 4	10	do	Do.
Do	7- 8	4	2- 4	0	Nil	Nil.
Second	9-10	6	7-10	2	Slight	Total.
Do	11-12	6	7-10	5	Total	Do.
Do	13-14	6	7-10	10	do	Do.
Do	15-16	6	7-10	0	Nil	Nil.
Third	17-18	8	12-16	2	Slight	Total.
Do	19-20	8	12-16	5	Severe	Do.
Do	21-22	8	12-16	10	Total	Do.
Do	23-24	8	12-16	0	Nil	Nil.
Fourth	25-26	10	19-24	2	Negligible	Severe.
Do	27-28	10	19-24	5	Slight	Total.
Do	29-30	10	19-24	10	Severe	Do.
Do	31-32	10	19-24	0	Nil	Nil.
Fifth	33-34	15	31-32	2	do	Slight.
Do	35-36	15	31-32	5	Negligible	Severe.
Do	37-38	15	31-32	10	Slight	Total.
Do	39-40	15	31-32	0	Nil	Nil.

[b] Infestation in first and second series is considered "early." Infestation in third, fourth, and fifth series is considered "late." When there are on the average 1 to 2 hoppers per panicle, the infestation is considered "slight;" 3 to 5 hoppers per panicle, the infestation is considered "moderate;" 6 to 10 hoppers per panicle, the infestation is considered "severe."

severely and slightly damaged, respectively. On the other hand, those that had two, five, and ten *I. clypealis* were not destroyed, very slightly destroyed, and slightly destroyed, respectively. The damage done to this last series by *I. clypealis* was so slight that the panicle had as many fruits as the checks.

In summarizing the results thus obtained one is led to believe that the larger species, *Idiocerus niveosparsus,* is by far the more destructive of the two. This is so, perhaps, not only because it is a faster sucker owing to its larger size, but also probably because the period of its activities with the flower is longer than that of the small species. It is able to lay eggs even on already withering inflorescences and on panicles of young fruits, whereas the small species, *I. clypealis,* can lay eggs only in the fresh flower buds. Past this stage of the development of the flower this species does not seem capable of causing damage to the inflorescences on account of its inability to reproduce thereon as above stated.

It was also made manifest that if the infestation is two or more adults on the average per panicle, the situation should be considered serious.

SPRAYING EXPERIMENT

It might be well to mention here what other investigators have found to be effective treatments for this pest. Ramachandra Rao,(5) in reporting his work on the mango-hopper problem in India, recommended the following remedial measures which he claims to be effective:

> 1. A preliminary spray of Bordeaux mixture to be given to the inflorescence as the flowers begin to open for preventing the appearance of the mildew; to be repeated once or twice if the mildew be not controlled by the first spray. 2. A thorough spray with fish oil resin soap to be given if hopper is noticed; to be repeated at intervals of a week in case further hatchings are noticeable. It is necessary in this connection to lay special stress on thoroughness of spraying, care being taken to drench the panicles to make sure that all the hoppers are reached, since inefficient spraying is but waste of effort. A spray of lead arsenate may also be given in case caterpillars are found attacking the inflorescences. 3. Lastly, when fruits have set, a supply of irrigation water to be arranged to be given to the trees in case it be feasible. For the dry system of cultivation, a scheme of thorough intercultivation should be adopted, having for its object conservation of soil moisture so as to counteract the heavy fruit-fall.

Palo(4) in his report on mango-blossom spraying experiments in Muntinlupa, Rizal Province, found the following remedial measures effective in increasing the yield of the treated trees many times over the control:

> (*a*) A preliminary application of rather strong Bordeaux-lead arsenate given while the inflorescence buds were bursting. (*b*) A second spray of weaker Bordeaux mixture to which nicotine sulphate and lead arsenate were added. (*c*) A third spray of nicotine-soap solution when a new brood of the hopper was noticed, and repeated at intervals of three to six days when further hatchings were observed. (*d*) Another spray of Bordeaux mixture-nicotine sulphate-lead arsenate when the petals were withering.

In the first report above mentioned the presence of mildew and caterpillars in association with the hoppers apparently made the remedial measures somewhat complicated for a layman to follow. In like manner, in the second report the presence of anthracnose and tip-borer in association with the hoppers made the remedial measures therefor also quite complicated for a grower to follow. By splitting both and eliminating those that are not of immediate necessity for the present purpose, fish-oil-resin soap and nicotine-soap, the backbones of the first and the second treatments, respectively, became manifest and the subject of a more thorough study herein reported.

There was a long spell of dry days when these spraying experiments were conducted, and no trace of anthracnose infection was noted and the tip-borer infestation was not serious. For this reason most of the time during the first lap of the work was devoted to spraying for the hoppers alone and to a search for a more effective and economical spray than the nicotine-soap. These experiments were conducted at four places in Rizal Province; namely, Pasay, Novaliches, Bayanan, and Muntinlupa.

During the early part of this investigation when a general survey of the seriousness of the problem was being made, it was noted (*a*) that there were a very few trees having relatively few hoppers or slight infestation, (*b*) that there were trees having many hoppers or moderate infestation, and (*c*) that there were a few others with abundant hoppers or severe infestation which might occur when the flower heads were only from 1 to 2 centimeters long. For convenience, all the trees that showed slight infestation and those with early severe infestation are discussed on page 247.

NICOTINE-SOAP SPRAY

Nicotine as an insecticide has been the subject of more or less thorough study in the last one hundred years, and has been considered a great factor in the warfare against insect pests. It has been used in the form of tobacco dust, tobacco decoction, or nicotine sulphate solution, the last proving the most effective and economical. Wardle(9) and Buckle suggested that the physiological effect of nicotine upon the insect appears to be one of paralysis of the motor centers, brought about by a condensation of the vapor upon the walls of the tracheæ and subsequent absorption of the liquid by the tissues. This belief seems to have been confirmed by Pickett(10) and others, who reported that nicotine kills by paralyzing the insects after the nicotine vapors have entered the bodies through the breathing pores; that nicotine volatilizes more quickly if the solution has been rendered alkaline, which is easily done by the addition of soap. Palo's(4) report indicated that nicotine-soap helped in controlling the pest. To verify this and to find out the concentration best suited, the following spraying experiments were conducted using different concentrations of "Black leaf 40" (nicotine sulphate) in a 0.36 per cent soapsud solution, such as given in the following formulas:

Formula 1.	
"Black leaf 40" (nicotine sulphate), cc	120
Chinese yellow laundry soap, g	360
Water, l	100
Formula 2.	
"Black leaf 40" (nicotine sulphate), cc	100
Chinese yellow laundry soap, g	360
Water, l	100
Formula 3.	
"Black leaf 40" (nicotine sulphate), cc	80
Chinese yellow laundry soap, g	360
Water, cc	100

The spray solutions were prepared in the following manner: To make the stock solution, 360 grams of Chinese yellow laundry soap sliced into small pieces, were dissolved in 10 liters of hot (70° to 80° C.) water in a gasoline can. To this stock solution 120 cubic centimeters of "Black leaf 40" were added in a 50-gallon barrel and the resulting solution diluted with enough water to make 100 liters of Formula 1 nicotine-soap spray solution ready for use. The rest of the spray solutions were prepared in like manner but using the corresponding quantities of "Black leaf 40" (nicotine sulphate) indicated in the formulas. Greater or less quantity of the spray solution as needed by the experiments was prepared by either increasing or reducing, proportionally, the amounts of the ingredients given under each formula.

The first spraying test with nicotine-soap of Formula 1 was conducted on two pico trees in Pasay February 13, 1932. The trees were in full bloom with some flowers already opened and showing signs of slight damage due to the severe infestation by *Idiocerus niveosparsus*. This was done to find out what good the spray would do on a tree whose infestation was fairly advanced. Only two trees were treated, because all the others had withered on account of the pest. One-half of the crown of each tree was sprayed, leaving the other half as check. The first spraying was done February 13, 1932, followed by the second, February 17, or four days after, and the third, February 25.

The last had to be applied because of the new brood of nymphs resulting from a reinfestation when the young fruits were already setting. Care was taken to wet thoroughly with the spray solution all the inflorescences and twigs of the treated trees. Cursory examination of the inflorescences after each treatment revealed that the spray was effective as indicated by the great mortality among the young hoppers. In this treatment and in all other subsequent spraying experiments the amount of solution used, as well as the time consumed in the operation, was noted for future reference.

The spraying outfit consisted of Gould's hand spray pump No. 1129 fitted with a 20-meter rubber hose and a Bordeaux nozzle tied to a 5-meter bamboo rod. Two men performed the work; one operated the pump, and the other, holding the bamboo rod with the nozzle, applied the spray to the flowers, leaves, and twigs. The tops of the trees were sprayed with the aid of a 9-meter bamboo ladder provided with props (Plate 10, figs. 1 and 2).

The continuation of the spraying experiments with different strengths of nicotine-soap series was conducted at the hacienda of Dr. N. Jacinto in Novaliches. Five carabao trees were used. They are the outgrowths of the main branches of a carabao tree about a century old that was blown down by a terrific storm years ago. All of them were blooming profusely and showing a more or less even distribution of *Idiocerus clypealis* hopper infestation.

February 16, 1932, one-half of the crown of each of the first two trees was treated with nicotine-soap of Formula 1; one-half of those of the second two trees with nicotine-soap of Formula 2; and one-half of the fifth with nicotine-soap of Formula 3. The remaining five halves were held unsprayed as checks.

Spraying of all the five half-trees was repeated twice to make three applications in all at an interval of three days. Hardly any appreciable difference between the efficacy of the different spray solutions could be noted in as much as in every instance the nymphs died once they got wet with any one of the preparations. It was, nevertheless, noted that more of the less-concentrated solutions had to be used per unit area than the more concentrated to make them as effective. Care was taken in each case to make the application thorough, for it was noted that the success of the treatment depended much on the thoroughness of application. After the third spraying no additional application was made as there were no new broods of the nymphs coming out.

The next spraying experiment with Formula 2 of nicotine-soap spray was carried out in the Barrio of Bayanan, Muntinlupa. Four carabao and three pico trees in full bloom and with more or less uniform hopper infestation, preponderantly *Idiocerus clypealis,* were used in this experiment, spraying one-half of the crowns February 18, 1932, and repeating two or three times at three or four days interval, depending on the prevalence of the infestation.

Upon maturity during the first week of May, 1932, counts of all the fruits on the trees treated with nicotine-soap including the checks were made. The results are summarized in Table 8.

TABLE 8.—*Results of spraying for blossom-blight hoppers with nicotine-soap solutions containing 0.36 per cent soap and different amounts of "Black leaf 40."*

Variety.	Approximate average area of half crowns with flowers.	Concentration of "Black leaf 40" in the nicotine-soap mixture.	Average amount of spray used.	Average yield of half trees.		Average yield per 100 square meters of crown.	
				Treated.	Check.	Treated.	Check.
	sq. m.	*Per cent.*	*Liters.*	*Fruits.*	*Fruits.*	*Fruits.*	*Fruits.*
Pico[c]	50.5	0.12	135.00	752.0	154.0	1,489.1	304.9
Do	50.5	0.12					
Carabao	50.5	0.12					
Do	50.5	0.12					
Do	74.0	0.10	389.44	1,322.0	293.4	1,786.5	396.5
Do	74.0	0.10					
Do	74.0	0.10					
Pico	74.0	0.10					
Carabao	74.0	0.10					
Do	74.0	0.10					
Pico	74.0	0.10					
Do	74.0	0.10					
Carabao	74.0	0.10					
Do	47.0	0.08	300.00	717.0	135.0	1,525.4	287.2

[c] When the first spray was applied there was already some perceptible damage caused by *Idiocerus niveosparsus* on about 10 to 15 per cent of the inflorescences of the first two pico trees.

SOAPSUD SPRAY

For more than a century soap has held a foremost place in the control of many insect pests. Numerous findings have been written on its insecticidal value, mostly as an emulsifier, spreader, larvicide, dip, and as contact spray for soft-bodied insects, like plant lice and aphids, some accounts of which have been published by Wardle,(9) Bourcart,(11) and others. In the campaign conducted by the Bureau of Plant Industry of the Philippine Government against the serious outbreak of the coconut leaf-miner (*Promecotheca cumingi* Baly) in almost all the coconut districts of the Archipelago in 1930, Roxas(12) recommended the use of soapsud sprays, preferably with the addition of either nicotine sulphate or arsenate of calcium or lead. The senior author, while working as plant pathologist for the Philippine Packing Corporation in 1930, had the opportunity of investigating and demonstrating the value of soap in the control of the pineapple mealybug (*Pseudococcus brevipes* Ckl.) responsible for the pineapple wilt. Again, it was found in the first series of the spraying experiments with different concentrations of "Black leaf 40" in a soapsud solution of 0.36 per cent, as discussed in the preceding paragraphs, that hardly any difference could be noted by occular observation between the killing power of the spray solutions containing 0.12, 0.1, and 0.08 per cent "Black leaf 40," all having shown 100 per cent efficiency when applied with thoroughness, which seems to indicate the probability of soap as being the main factor in the combination. All this information, pointing to the value of pure soap as an effective insecticide, precipitated a determined action to look into its possibilities as a cheap and effective spray for the control of the mango blossom-blight hoppers.

Relative killing power of the Chinese yellow laundry soap of different strengths.—Soapsud solutions of various concentrations such as 0.1, 0.2, 0.3, 0.4, 0.5, 1, 1.5, 2, and 2.5 per cent were prepared in 3-liter lots, each in a beaker of 4-liter capacity. The test was conducted outdoors under a mango tree with fully developed inflorescences showing the different nymphal stages of *Idiocerus clypealis* and *I. niveosparsus* in great abundance.

Starting from the lowest and ending with the highest concentration in gradual succession, twenty uniform panicles of the inflorescences were submersed in the solution one by one, each lasting about two seconds, taking the time elapsing from the moment they were taken out until the time when all the nymphs succumbed to the effects of the treatment. This procedure was followed throughout until all the tests in the whole series were completed, as given in Table 9. In these tests and in all subsequent tests for the killing power of the solutions, submersion was preferred over spraying in order to have a uniform wetting of the nymphs which was found very necessary in eliminating as much as possible the source of probable error in the computation of the relative killing power of each solution in terms of the time that elapses between the wetting and the killing of the hoppers. This condition cannot be attained by spraying, owing to the fact that the nymphs are quite evasive, going from side to side of the panicle to avoid the spray, thus the time of killing power obtainable thereof becomes very elastic and unreliable.

TABLE 9.—*Relative killing power of different concentrations of the Chinese yellow laundry soap.*

Strength of solution.	Number of panicles tested.	Average killing power.
Per cent.		*Seconds.*
2.5	20	4
2.0	20	4
1.5	20	5
1.0	20	7
0.5	20	11
0.4	20	16
0.3	20	22
0.2	20	([a])
0.1	20	([b])

[a] Killed first to third stages only.

[b] Killed first stage only.

It is shown in Table 9 that the maximum concentration at which 100 per cent kill could be attained in the least possible time was at about 1.5 to 2 per cent, while the minimum concentration at which to attain the same effect but at a longer duration was at about 0.3 per cent. These results seem to indicate that the right concentration of soap solution for mango blossom-blight hopper control lies midway between 0.4 and 0.5 per cent, beyond which the solution would either be too weak to be effective and economical, or too strong to be feasible.

Comparative efficacy of the different kinds of soap.—A solution of 0.5 per cent concentration of each of various kinds of soap was prepared, and each was tested for its killing power as a control for the mango blossom-blight hoppers. The same procedure of testing as in the preceding experiment was followed throughout the entire series. The results are given in Table 10, in descending order from the most effective to the least effective.

TABLE 10.—*Comparative efficacy of various kinds of soap used for the control of blossom-blight hoppers.*

Kind of soap.	Strength.	Panicles tested.	Average killing power.
	Per cent.		*Seconds.*
Chinese yellow	0.5	20	11
Señorita	0.5	20	12
Palmolive	0.5	20	12
Resin soap	0.5	20	15
Ivory	0.5	20	16
Chinese white	0.5	20	17
Lenox	0.5	20	17
Sanitary	0.5	20	22
Chinese raw	0.5	20	Nil.

From the standpoints of efficacy and cheapness of material, it is shown in the tabulation above that the Chinese yellow laundry soap leads, closely followed by Señorita and resin soaps. This Chinese yellow laundry soap is a local product from coconut oil.

The effect of heat on the killing power of soapsud.—When soapsud solutions ranging from 0.1 to 0.5 per cent were heated at from 40° to 45° C. and a comparative test of their killing power was conducted in the same way as in the unheated series, the results shown in Table 11 were obtained.

TABLE 11.—*Effect of heat on the killing power of soapsud for the control of blossom-blight hoppers.*

Strength of soap solution.	Panicles tested.	Average killing power.	
		Cold solution (28°–29° C.).	Hot solution (40°–45° C.).
0.1	20	Killed 1st stage only	Killed 1st and 2d stages only.
0.2	20	Killed 1st to 3d stages only	Killed in 9 seconds.
0.3	20	Killed in 22 seconds	Killed in 5 seconds.
0.4	20	Killed in 16 seconds	Instantaneous.
0.5	20	Killed in 11 seconds	Do.

Heating the solution to a temperature ranging from 40° to 45° C. (which is not too hot for the hand to withstand in submersion for a minute or so) greatly increased the killing power of the soap solutions, so much so that a 0.2 per cent solution accomplished 100 per cent kill two seconds quicker than a 0.5

per cent cold solution did. In view of the cheapness of soap the practicability of heating the solution is dubious, however.

The effect of "sticker" on the killing power of soapsud.—Three sets of a 0.4 per cent soapsud solution of 3 liters each were prepared. Then 7.5 grams of fine pottery clay were added to the first set and a good emulsion was made by thoroughly stirring the solution. The second solution was prepared by adding 3 cubic centimeters of resin-sal-soda sticker (made by dissolving 1 part of resin in 1 part of sodium hydroxide, diluting it with enough water to make 1 liter of the solution) to the soapsud solution. The third solution was kept without the sticker as check. The same procedure of testing for the killing power as discussed in the preceding paragraphs was followed in this experiment. The results are noted in Table 12.

TABLE 12.—*Effect of "sticker" on the killing power of soapsud solution.*

Solution.	Panicles tested.	"Sticker" added.	Average killing power.
			Seconds.
Soapsud, 0.4 per cent	20	Clay, 0.25 per cent	12
Do	20	Resin, 0.1 per cent	12
Do	20	None	16

It may be seen from Table 12 that the addition of either sticker increased the killing power of the soapsud solution, but the increase does not seem to be sufficient to warrant its use in practice.

FIELD APPLICATIONS

The results of the preceding experiments tend to show that soapsud as a spray for mango blossom-blight hoppers, even without the addition of any other insecticide, is very promising. To determine its practical usefulness in combating this pest the following spraying experiments were carried out in Bayanan, Muntinlupa, beginning February 18, 1932. The experiments were laid out as follows:

Three carabao and eleven pico trees in full bloom and showing a more or less uniform distribution of leaf-hoppers, mostly *Idiocerus clypealis*, were sprayed with a 0.5 per cent soapsud solution on one-half of the crowns, leaving the other halves unsprayed as checks. Spraying was repeated two or three times at two to five days' intervals, depending on the prevalence of the young hoppers. The results are given in Table 13.

TABLE 13.—*Results of spraying for blossom-blight hoppers, Idiocerus clypealis and I. niveosparsus, with 0.5 per cent soapsud solution.*

Variety.	Approximate area of half crown.	Amount of spray used.	Yield on half trees.		Average yield per 100 square meters of crown.	
			Treated.	Check.	Treated.	Check.
	sq. m.	*l.*	*Fruits.*	*Fruits.*	*Fruits.*	*Fruits.*
Carabao	49.0	260	657	224	1,341	457
Do	24.0	220	312	83	1,300	346
Do	60.0	400	1,153	192	1,922	320
Pico	53.0	260	413	144	779	272
Do	68.0	560	879	256	1,293	376
Do	59.0	240	722	128	1,224	217
Do	55.0	560	592	96	1,076	175
Do	67.5	440	802	223	1,188	330
Do	79.0	640	1,174	329	1,486	416
Do	20.0	180	189	48	945	240
Do	32.0	240	210	45	656	141
Do	26.0	220	220	33	846	127
Do	36.0	110	295	49	819	136
Do	44.0	160	456	92	1,036	209
Average	48.0	320.7	576.7	138.5	1,136.5	268.7

This was immediately followed by another series in which 0.4 per cent soapsud solution was used to spray seventeen carabao and nine pico trees at the hacienda of Mr. Vicente Madrigal in Muntinlupa. These trees differed from those of the first series in the profuseness of the flowers, ranging from few to abundant, resulting perhaps from late flowering. The hopper infestation ranged from slight to severe, but generally from moderate to severe, with *Idiocerus clypealis* predominating. Beginning March 17, 1932, the half crowns of the trees showing from first to third stages of the hopper nymphs were sprayed, leaving the other halves untreated as checks. This was repeated three to six times at two- or three-day intervals, depending on the prevalence of the nymphs. The results are given in Table 14.

In every instance the treatment showed 100 per cent kill on the hopper nymphs that got wet with the spray solution as has been the case generally whenever thorough application was made. Like the nicotine-soap, soapsud solution, particularly 0.5 per cent, was so effective that even the adult hoppers perished when they got completely drenched. It was found, however, that no matter how thorough the application a few of the insects managed to avoid the spray. The adults escaped by flight, as soon as they heard the noise produced by the spraying.

TABLE 14.—*Results of spraying for blossom-blight hoppers with 0.4 per cent soapsud solution.*

Variety.	Approximate area of half crown.	Amount of spray used.	Yield on half trees.		Average yield per 100 square meters of crown.	
			Treated.	Check.	Treated.	Check.
	sq. m.	l.	*Fruits.*	*Fruits.*	*Fruits.*	*Fruits.*
Carabao	39.0	540	260	78	666	200
Do	88.0	1,240	1,008	338	1,145	384
Do	75.0	820	519	187	692	249
Do	113.0	820	432	93	382	82
Do	43.0	420	193	0	449	0
Do	88.0	740	397	132	451	150
Do	73.5	930	775	105	1,054	143
Do	53.0	690	714	231	1,347	436
Do	27.0	370	227	59	841	219
Do	66.5	960	620	157	932	236
Do	37.5	920	412	45	1,099	120
Do	27.0	480	196	23	726	85
Do	52.0	610	603	44	1,160	85
Do	82.5	910	487	34	590	41
Do	52.5	700	405	107	771	204
Do	25.0	290	108	38	432	152
Do	48.0	860	368	10	767	21
Pico	94.0	890	1,326	257	1,411	273
Do	98.0	1,400	925	134	944	137
Do	87.0	1,120	684	78	786	90
Do	83.5	960	486	164	582	196
Do	81.5	860	441	58	541	71
Do	94.0	1,330	853	184	907	196
Do	60.5	1,020	1,148	166	1,898	274
Do	28.5	340	185	27	649	95
Do	39.0	420	269	62	690	159
Average	63.7	793.85	540	108.1	838.9	165.3

SOAPSUD VS. NICOTINE-SOAP

In view of the fact that soapsud when used alone, even at the strength of 0.3 per cent, could cause 100 per cent kill on the nymphs of the mango-blight hoppers and, owing to the rather insignificant difference in the killing power between the nicotine-soap sprays of formulas 1, 2, and 3 containing 0.12, 0.1, and 0.08 per cent of "Black leaf 40," respectively, in a 0.36 per cent soapsud solution as pointed out under nicotine-soap spray, it was suspected that soap was the main active principle in the combinations. It was felt necessary, therefore, to lay out some more experiments under more or less controlled conditions whereby the relative value of soap and "Black leaf 40" taken individually and in combination, to attain the best possible results, could be determined. The following experiments were conducted to clarify this point:

Seven and one-half liters of 0.5 per cent soapsud solution and an equal amount and strength of "Black leaf 40" solution were prepared in two separate containers. Five beakers of 4-liter capacity were numbered from 1 to 5, respectively; then into each of the containers the solutions were poured in single and combined forms, in the following order: Beaker 1, 3 liters of soapsud; beaker 2, 3 liters of "Black leaf 40;" beaker 3, 1.5 liters of soapsud and 1.5 liters of "Black leaf 40;" beaker 4, 2 liters of soapsud and 1 liter of "Black leaf 40;" and beaker 5, 1 liter of soapsud and 2 liters of "Black leaf 40."

Following exactly the same procedure as that given under soapsud spray, the relative killing power of each solution thus prepared was tested. The results are given in Table 15.

TABLE 15.—*Relative killing power of 0.5 per cent soapsud solution and 0.5 per cent "Black leaf 40" solution when used singly and in combination.*

Beaker No.	Solution.	Proportion of the combination.	Strength.		Killing power.
			Soapsud.	Nicotine-soap.	
			Per cent.	*Per cent.*	*Seconds.*
1	Soapsud alone		0.5		11
2	"Black leaf 40" alone			0.5	660
3	Soapsud plus "Black leaf 40"	1:1	0.25	0.25	16
4	Do	2:1	0.33	0.17	12
5	Do	1:2	0.17	0.33	26

It may be seen from Table 15 that soap seems to be the main factor in the nicotine-soap combination spray; that 0.5 per cent soapsud could kill all the nymphal stages of the mango blossom-blight hoppers in eleven seconds when the infested panicle was submerged in the solution for about two seconds; and "Black leaf 40" of the same strength could not kill by the same treatment in less than eleven minutes. This discrepancy in their killing power may be explained by the fact that the toxicity or efficacy of nicotine sulphate or "Black leaf 40" as a contact insecticide depends on the availability of its nicotine content, which Pickett(10) and others believe to be dependent in turn, at least in part, on the alkalinity produced in the solution by the addition of soap or other alkalies. The same table further shows that a combination of the two in any one of the proportions tried, as 1 to 1, 2 to 1, and 1 to 2 did not give as good results as soapsud of the same strength taken alone. There was an indication, however, that better results could be attained by using more soap in the combination. To follow this up the following experiments were carried out:

Fifteen liters of 0.5 per cent soapsud solution were prepared; equal amounts were placed in five 4-liter beakers, which were numbered from 1 to 5, respectively. Leaving out the first which was held as check, undiluted "Black leaf 40" was added to each of the four solutions in amounts of 0.75, 1.5, 2.5, and 3 cubic centimeters, respectively, and the resulting solution was stirred for some time. The efficacy of each solution thus prepared was then tested in the same way as in the preceding tests.

At the completion of the test it was deemed necessary to run two more of the same series, but with 0.4 and 0.3 per cent instead of 0.5 per cent as the stock soapsud solutions. The results of the three series are given in Table 16.

TABLE 16.—*Comparative efficacy of soapsud and nicotine-soap solutions of various concentrations for blossom-blight hoppers.*

Series.	Panicles used.	Solution (3 liters each).	Strength.		Killing power.
			Soapsud.	Nicotine-soap.	
			Per cent.	*Per cent.*	*Seconds.*
First	20	Soapsud alone	0.5		11
Do	20	Soapsud plus "Black leaf 40"	0.5	0.025	9
Do	20	do	0.5	0.05	8
Do	20	do	0.5	0.075	8
Do	20	do	0.5	0.1	8
Second	20	Soapsud alone	0.4		17
Do	20	Soapsud plus "Black leaf 40"	0.4	0.025	16
Do	20	do	0.4	0.05	14
Do	20	do	0.4	0.075	15
Do	20	do	0.4	0.1	13
Third	20	Soapsud alone	0.3		22
Do	20	Soapsud plus "Black leaf 40"	0.3	0.025	19
Do	20	do	0.3	0.05	17
Do	20	do	0.3	0.075	18
Do	20	do	0.3	0.1	18

From Table 16 it may be seen that nicotine-soap solutions of various concentrations proved to be more effective than soapsud alone. The combinations that gave the best results are those containing from 0.05 to 0.1 per cent "Black leaf 40," the average killing power being 13 seconds for 0.05 per cent, 13.6 seconds for 0.075 per cent, and 13 seconds for 0.1 per cent. It appears that the average killing power of 0.05, 0.075, and 0.1 per cent nicotine-soap solutions is practically the same, which would seem to convey the idea that the excess of "Black leaf 40" over 0.05 per cent does not give any additional benefit; if so, it might be due to the nonliberation of nicotine in the excess "Black leaf 40." While this explanation seems tenable, it remains doubtful, nevertheless, whether the same effect could be obtained if the solutions were applied in the form of spray.

There seems to be no doubt, however, that soap is the main active principle in the combination. It may not be amiss to mention the particular properties or constituents of soap responsible for killing the insects that are treated. Various opinions have been expressed on this question, among which mechanical obstruction of the body openings and the caustic properties of the alkaline constituents have apparently received the support of many researchers. Siegler(13) and Popenoe discredited these beliefs and advanced the theory based on their findings that it is the release of the acid components through hydrolytic dissociation that causes the toxicity of soaps when used as contact sprays. They say:

> If the mechanical obstruction of the body openings or the action of the free alkali is responsible for the toxicity of soap, an increase of toxicity should be obtained by every increase in concentration. On the other hand, if the free fatty acids are the toxic agents, and these are dependent for their action upon absorption through the insect membranes, the familiar characteristics of insecticidal soap solutions might be expected to assert themselves.

In conformity with this theory the senior author found (as shown in Table 9) that by increasing the concentration of Chinese yellow laundry soap beyond 2 per cent no corresponding increase in toxicity to the blossom-blight hoppers was obtained; that 0.5 per cent sodium hydroxide solution when tested for killing power proved to be devoid of toxicity even to the youngest nymphs; and that a solution of 0.5 per cent lactic acid in pure form was as nontoxic as the alkali, while a fermented milk which contains probably not as much lactic acid proved toxic. The last point would seem to suggest that the decomposition products of the fat content of milk are responsible for the toxic effect shown. The theory that the fatty acid content of soap is the active principle in soapsud when used as a contact insecticide, is thus supported.

How the fatty acids kill the insects is not well understood. Siegler(13) and Popenoe advanced the hypothesis that the fatty acids in a crystalloid state penetrate the insect's body walls and tracheæ, thus gaining immediate hæmolytic action on the hæmolymph and body cells. On the other hand, Shafer(14) found that heat of certain intensities and the several contact insecticides he studied (gasoline, carbon disulphide, hydrocyanic acid gas, sodium fluoride, etc.), when used at a concentration sufficient to kill insects, deleteriously affected the activities of reductases, catalases, and oxidases, usually in unequal degree, thus disturbing the natural or normal balance of such activities. These activities being of vital importance to the life processes of the tissue cells, the above-stated deleterious action must be an important factor in causing the death of the treated insects. This hypothesis goes far in explaining why soapsud solutions of various concentrations, when heated at from 40° to 45° C. (Table 11), increase their toxicity to the blossom-blight hoppers much more than when they are applied at room temperature.

In view of the results obtained in the foregoing experiments, the question as to which of the two spray solutions (soapsud or nicotine-soap) is the better for the purpose, is raised. Spraying experiments were then laid out by using; first, 0.5 per cent soapsud vs. nicotine-soap, Formula 2, containing 100 cubic centimeters "Black leaf 40," 360 grams Chinese yellow laundry soap and 100 liters water; second, 0.4 per cent soapsud vs. nicotine soap, Formula 2; and third, 0.4 per cent soapsud vs. nicotine-soap, Formula 4, containing 50 cubic centimeters "Black leaf 40," 300 grams Chinese yellow laundry soap, and 100 liters water.

The first set was conducted at Bayanan, Muntinlupa, beginning February 20, 1932. Half crowns of two carabao and two pico trees showing profuse inflorescences and a moderate to severe hopper infestation, mostly by *Idiocerus clypealis*, were sprayed with 0.5 per cent soapsud solution, while the other halves were sprayed with nicotine-soap solution, Formula 2, repeated four times at three-day intervals. For checks, four adjacent trees having practically the same crown area, profuseness of flowers, and hopper infestation were left unsprayed. The results are given in Table 17.

For lack of available trees in Bayanan the second set was immediately laid out after this at the hacienda of Mr. Vicente

Madrigal in Muntinlupa. In this set 0.4 per cent soapsud solution was tried vs. nicotine-soap, Formula 2, on three carabao and four pico trees with severe hopper infestation by both species, spraying half crowns with the former and the other half crowns with the latter. Four or five applications were given to each side at two- or three-day intervals, depending on the prevalence of the infestation. Check trees of the same number having practically the same crown area, profuseness of flower, and distribution of severe hopper infestation were chosen from the same lot. The results are given in Table 18.

TABLE 17.—*Results of spraying for blossom-blight hoppers with 0.5 per cent soapsud solution vs. nicotine-soap solution containing 0.36 per cent soap and 0.1 per cent "Black leaf 40."*

Variety.	Approximate area of half crown.	Amount of spray used.		Yield on half trees.		
		Soap.	Nicotine-soap.	Soap.	Nicotine-soap.	Check.
	sq. m.	*l.*	*l.*	*Fruits.*	*Fruits.*	*Fruits.*
Carabao	52.0	340	260	816	785	
Do	57.0	470	360	888	882	
Pico	73.0	460	360	1,230	1,420	
Do	44.0	330	280	570	710	
Average	56.5	400	315	876	949.2	138.7
Average yield per 100 square meters of crown				1,550.4	1,680.0	289.2

TABLE 18.—*Results of spraying for blossom-blight hoppers with 0.4 per cent soapsud solution vs. nicotine-soap solution containing 0.36 per cent soap and 0.1 per cent "Black leaf 40."*

Variety.	Approximate area of half crown.	Amount of spray used.		Yield on half trees.		
		Soap.	Nicotine-soap.	Soap.	Nicotine-soap.	Check.
	sq. m.	*l.*	*l.*	*Fruits.*	*Fruits.*	*Fruits.*
Carabao	97.0	720	400	612	709	
Do	56.0	800	620	823	1,024	
Do	113.0	1,450	750	1,352	1,701	
Pico	36.0	520	280	389	507	
Do	49.0	560	250	656	908	
Do	110.0	900	680	1,875	2,535	
Do	47.0	700	420	462	857	
Average	72.5	807.14	485.7	881.3	1,177.3	108.1
Average yield per 100 square meters of crown				1,215.6	1,623.9	170.2

The third set, which consisted of 0.4 per cent soapsud vs. nicotine-soap, Formula 4, was laid out on five carabao trees also at the hacienda of Mr. Vicente Madrigal, May 5, 1932. The trees had moderate amounts of flowers, and more or less the same crown area, with moderate hopper infestation, preponderantly of *Idiocerus clypealis*. The crown of each tree was divided into three equal parts; one part was treated with 0.4 per cent soapsud, another part with nicotine-soap, Formula 4, and the middle part was left unsprayed as check. Four applications were made on both sides at two- or three-day intervals, depending on the infestation. The results are given in Table 19.

TABLE 19.—*Results of spraying for blossom-blight hoppers with 0.4 per cent soapsud solution vs. nicotine-soap solution containing 0.3 per cent soap and 0.05 per cent "Black leaf 40."*

Variety.	Approximate area of half crown.	Amount of spray used.		Yield on half trees.		
		Soap.	Nicotine-soap.	Soap.	Nicotine-soap.	Check.
	sq. m.	*l.*	*l.*	*Fruits.*	*Fruits.*	*Fruits.*
Carabao	71.0	400	320	1,543	1,592	472
Do	64.0	380	360	727	696	133
Do	46.0	270	210	296	267	49
Do	56.0	420	380	343	241	30
Do	40.5	300	290	384	386	108
Average	55.5	354	312	658.6	636.4	158.4
Average yield per 100 square meters of crown			----------	1,186.7	1,146.7	285.4

It was noted in the first two cases in the three foregoing spraying experiments that nicotine-soap was more effective than soapsud of the concentrations tried for the control of the blossom-blight hoppers. This was indicated first, by the greater rapidity with which it kills the hoppers and, second, by the smaller amount of solution consumed per unit area of the crown treated. It was similarly observed that both soapsud and nicotine-soap of higher concentrations were more efficient killers than the same solutions of less concentrations. This would seem to show that in the case of nicotine-soap solution the results obtained from immersion tests (Table 16) are not indicative of the true efficiency of the spray, that nicotine-soap is more effective as a spray than as a dip, and that the proper evaluation of the efficacy of nicotine-soap as a contact insecticide can only be made through actual spraying.

Whether or not these observations concur with the results attained in terms of pesos and centavos net profit[5] realized from each treatment is shown by Table 20, which summarizes all the preceding spraying experiments.

The net gain obtainable from each treatment is variable, of course, depending on various factors, among which are the market price of the crop so produced which oscillates between 2 and 15 pesos per kaing, cost of spray materials, cost of labor, and success of the spraying; the last, in turn, depends on several factors, principal among which are the right time and thoroughness of the application.

SPRAYING TREES WITH SLIGHT INFESTATION OCCURRING LATE AND TREES WITH SEVERE INFESTATION OCCURRING EARLY

During the early part of this investigation when the seriousness of the problem was being surveyed, it was noted that some trees had but relatively few hoppers or slight infestation, others had many hoppers or moderate infestation, and still a few others had abundant hoppers or severe infestation that might have occurred as early as when the flower heads were only from 1 to 2 centimeters long. As previously mentioned in the early part of the spraying experiments, all of the sprayed trees that fall under the first and third classifications were set aside for this later discussion.

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[5] The computation for net profit obtained from all the spraying experiments was based on the following figures:

Cost of spray materials.—Chinese yellow laundry soap, 1 kilo, 0.20 peso; "Black leaf 40," 1 cubic centimeter (0.5-pound bottle of 190 cubic centimeters at 2.52 pesos), 0.133 peso.

Cost of labor for spraying.—Two laborers working together with a hand spray pump could discharge on the average about 89 liters of the spray in an hour, or about 800 liters in a day. The laborers were paid 0.80 peso each a day. At this rate it cost 0.002 peso to discharge 1 liter of the spray.

Cost of labor for picking.—A laborer working at 0.80 peso a day can pick on the average 1,250 fruits (or 10 kaings of the carabao variety) It costs to pick one fruit 0.00064 peso.

Value of mangos per kaing (variable).—Carabao: One kaing of 125 fruits at 3 pesos or 0.024 peso a fruit. Pico: One kaing of 175 fruits at 2.50 pesos or 0.0143 peso a fruit.

TABLE 20.—*Comparative expenses incurred in, and yield and profit obtained by, spraying mango trees of two varieties with soapsud and nicotine-soap to control blossom-blight hoppers.*

CARABAO VARIETY.

Series.	Treatment.	Trees treated.	Average area of crown.	Average yield per half tree.			Average value of the crop.			Average expenses (material and labor).		
				Soapsud.	Nicotine-soap.	Check.	Soapsud.	Nicotine-soap.	Check.	Soapsud.	Nicotine-soap.	Check.
			sq. m.	*Fruits.*	*Fruits.*	*Fruits.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*
1	Nicotine soap, 0.36 per cent soap +0.12 per cent "Black leaf 40" vs. checks	2	133	---------	1,329.0	308.0	---------	31.896	7.392	---------	3.652	0.197
2	Nicotine soap, 0.36 per cent soap+0.1 per cent "Black leaf 40" vs. checks	6	153	---------	1,437.8	329.8	---------	34.488	7.915	---------	7.073	0.211
3	Nicotine soap, 0.36 per cent soap +0.08 per cent "Black leaf 40" vs. checks	1	94	---------	717.0	135.0	---------	17.208	3.240	---------	4.466	0.086
4	Soap, 0.5 per cent vs. checks	3	88	707.8	---------	166.3	16.968	---------	3.991	1.331	---------	0.106
5	Soap, 0.4 per cent vs. checks	17	116	454.3	---------	98.8	10.903	---------	2.371	2.315	---------	0.063
6	Nicotine soap, 0.36 per cent soap +0.1 per cent "Black leaf 40" vs. soap, 0.5 per cent	2	110	852.0	833.5	207.9	30.448	20.004	4.989	1.760	5.499	0.183
7	Nicotine soap, 0.36 per cent soap +0.1 per cent "Black leaf 40" vs. soap, 0.4 per cent	3	177	929.0	1,144.6	150.8	22.296	27.470	3.619	3.364	10.203	0.097
8	Nicotine soap, 0.3 per cent soap +0.05 per cent "Black leaf 40" vs. soap, 0.4 per cent	5	111	658.6	636.4	158.4	15.806	15.273	3.801	1.412	3.292	0.101

Series.	Treatment.	Trees treated.	Average area of crown.	Average net returns.			Average net profit per half tree.		Average net profit per tree.		Average net profit per 100 square meters of crown.	
				Soapsud.	Nicotine-soap.	Check.	Soapsud.	Nicotine-soap.	Soapsud.	Nicotine-soap.	Soapsud.	Nicotine-soap.
			sq. m.	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*
1	Nicotine soap, 0.36 per cent soap +0.12 per cent "Black leaf 40" vs. checks	2	133	--------	28.244	7.195	--------	21.05	--------	42.10	--------	31.65
2	Nicotine soap, 0.36 per cent soap +0.1 per cent "Black leaf 40" vs. checks	6	153	--------	27.415	7.704	--------	19.71	--------	39.42	--------	25.76
3	Nicotine soap, 0.36 per cent soap +0.08 per cent "Black leaf 40" vs. checks	1	94	--------	12.742	3.154	--------	9.59	--------	19.18	--------	20.40
4	Soap, 0.5 per cent vs. checks	3	88	15.637	--------	3.885	11.75	--------	23.50	--------	26.70	--------
5	Soap, 0.4 per cent vs. checks	17	116	8.588	--------	2.308	6.28	--------	12.56	--------	10.83	--------
6	Nicotine soap, 0.36 per cent soap +0.1 per cent "Black leaf 40" vs. soap, 0.5 per cent	2	110	18.688	14.505	4.856	13.83	9.65	27.66	19.30	25.14	17.55
7	Nicotine soap, 0.36 per cent soap +0.1 per cent "Black leaf 40" vs. soap, 0.4 per cent	3	177	18.932	17.269	3.522	15.41	13.75	30.82	27.50	17.41	15.54
8	Nicotine soap, 0.3 per cent soap +0.05 per cent "Black leaf 40" vs. soap, 0.4 per cent	5	111	14.394	11.981	3.700	10.69	8.28	21.38	16.56	19.26	14.92
	Average gain for all treatments per 100 square meters of crown										19.87	20.97
	Average gain for the last three treatments per 100 square meters of crown										20.60	16.00

TABLE 20.—*Comparative expenses incurred in, and yield and profit obtained by, spraying mango trees of two varieties with soapsud and nicotine-soap to control blossom-blight hoppers*—Continued.

PICO VARIETY.

Series.	Treatment.	Trees treated.	Average area of crown.	Average yield per half tree.			Average value of the crop.			Average expenses (material and labor).		
				Soapsud.	Nicotine-soap.	Check.	Soapsud.	Nicotine-soap.	Check.	Soapsud.	Nicotine-soap.	Check.
			sq. m.	*Fruits.*	*Fruits.*	*Fruits.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*
1	Nicotine soap, 0.36 per cent soap +0.12 per cent "Black leaf 40" vs. checks	2	69	----------	175.0	0	----------	2.502	0	----------	2.353	0
2	Nicotine soap, 0.36 per cent soap +0.1 per cent "Black leaf 40" vs. checks	3	140	----------	1,090.3	220.6	----------	15.587	3.154	----------	7.109	0.141
4	Soap, 0.5 per cent vs. checks	11	98	541.1	----------	131.2	7.737	----------	1.876	1.330	----------	0.083
5	Soap, 0.4 per cent vs. checks	9	148	701.8	----------	125.5	10.035	----------	1.794	3.043	----------	0.080
6	Nicotine soap, 0.36 per cent soap +0.1 per cent "Black leaf 40" vs. soap, 0.5 per cent	2	117	900.0	1,065.0	227.8	12.870	15.229	3.257	1.761	5.807	0.146
7	Nicotine soap, 0.36 per cent +0.1 per cent "Black leaf 40" vs. soap, 0.4 per cent	4	120	845.5	1,201.7	101.8	12.090	17.184	1.455	2.417	7.290	0.065

Series.	Treatment.	Trees treated.	Average area of crown.	Average net returns.			Average net profit per half tree.		Average net profit per tree.		Average net profit per 100 square meters of crown.	
				Soapsud.	Nicotine-soap.	Check.	Soapsud.	Nicotine-soap.	Soapsud.	Nicotine-soap.	Soapsud.	Nicotine-soap.
			sq. m.	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*
1	Nicotine soap, 0.36 per cent soap +0.12 per cent "Black leaf 40" vs. checks	2	69		0.149	0		0.15		0.30		0.43
2	Nicotine soap, 0.36 per cent soap +0.1 per cent "Black leaf 40" vs. checks	3	140		8.478	3.013		5.47		10.94		7.81
4	Soap, 0.5 per cent vs. checks	11	98	6.407		1.793	4.61		9.22		9.41	
5	Soap, 0.4 per cent vs. checks	9	148	6.992		1.714	5.28		10.56		7.14	
6	Nicotine soap, 0.36 per cent soap +0.1 per cent "Black leaf 40" vs. soap, 0.5 per cent	2	117	11.109	9.422	3.111	8.00	6.31	16.00	12.62	13.68	10.79
7	Nicotine soap, 0.36 per cent +0.1 per cent "Black leaf 40" vs. soap, 0.4 per cent	4	120	9.673	9.894	1.390	8.28	8.50	16.56	17.00	13.80	14.17
	Average gain for all treatments per 100 square meters of crown										11.01	8.30
	Average gain for the last two treatments per 100 square meters of crown										13.74	12.48

Included in this test are two carabao trees with slight infestation, and one carabao and six pico trees with severe infestation. Half crowns of the trees were sprayed with 0.5 per cent soapsud solution four to five times at three-day intervals, leaving the other halves untreated as check. The results are given in Table 21.

DISCUSSION OF RESULTS

NICOTINE-SOAP SPRAY

It is shown in Table 8, first, that nicotine-soap spray, Formula 1, containing 0.36 per cent soap and 0.12 per cent "Black leaf 40" (nicotine sulphate), when used to control the blossom-blight pest of mango increased on the average the yield of the treated trees 4.9 times that of the check or the untreated (Plate 11, figs. 1 and 2); second, that when the amount of "Black leaf 40" in the same combination was reduced to 0.1 per cent, Formula 2, the yield of the treated trees was increased 4.5 times that of the check; and, third, that when the amount of "Black leaf 40" was further reduced to 0.08 per cent, Formula 3, the yield of the treated trees was increased 5.3 times that of the check. It would appear offhand from these results that there was not much difference between the treatments. If there be any at all, it is in favor of Formula 3 that has the least amount of nicotine in the solution. This difference in the yield of fruits, however, conceals the true efficiency of each treatment. By splitting the two varieties apart and computing the total expenses incurred (including the labor and the spray materials used) in producing the corresponding yields per 100 square meters of crown, the net profit realized from each treatment on the carabao variety as shown in Table 20, series 1 to 3, is 31.65, 25.76, and 20.40 pesos for the first, second, and third treatments, respectively.

It is interesting to note that the gradual increase in the net profit coincides with the gradual increase in the concentration of the corresponding spray solutions used. In other words, the net profit obtained by spraying carabao variety with nicotine-soap is directly proportional to the increase in the concentration of the spray solution used. It would seem from this that greater profit may be realized by spraying carabao mangos with nicotine-soap solution, Formula 1, containing not less than 0.12 per cent of "Black leaf 40" than by using less-concentrated solutions. This may be explained perhaps by the fact that, in order to attain the same killing effect, a greater amount of the

TABLE 21.—*Results of spraying with 0.5 per cent soapsud solution trees with slight infestation and trees with severe, early infestation by blossom-blight hoppers.*

Tree No.	Variety.	Approximate area of half crown.	Sprayings.	Amount of spray used.	Yield on half trees.		Value of the crop.	
					Treated.	Check.	Treated.	Check.
		sq. m.		*l.*	*Fruits.*	*Fruits.*	*Pesos.*	*Pesos.*
24	Carabao	60.5	3	260	1,813	784	31.51	18.82
44	do	90.5	5	860	2,077	1,996	49.85	47.90
6	do	49.0	5	470	646	412	15.50	9.82
12	Pico	72.5	5	610	1,098	1,078	15.70	15.42
45	do	112.0	8	500	1,897	1,063	26.93	15.20
60	do	47.0	6	500	186	19	2.66	0.271
61	do	36.0	6	450	196	32	2.80	0.457
64	do	76.5	6	800	273	4	3.90	0.057
65	do	49.0	6	560	185	8	2.65	0.114

Tree No.	Variety.	Expenses.		Net returns.		Net profit per tree.	Net profit per 100 square meters of crown.	Time and volume of infestation.
		Treated.	Check.	Treated.	Check.			
		Pesos.	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	
24	Carabao	1.62	0.50	29.89	18.32	+11.57	+19.12	Slight-late.
44	do	3.91	1.28	45.94	46.62	— 0.68	— 0.75	Do.
6	do	1.82	0.26	13.68	9.63	+ 4.05	+ 8.26	Severe-early.
12	Pico	2.53	0.69	13.17	14.73	— 1.56	— 2.15	Do.
45	do	2.71	0.68	24.22	14.52	+ 9.70	+ 8.66	Do.
60	do	1.62	0.012	1.04	0.26	+ 0.78	+ 1.66	Do.
61	do	1.48	0.020	1.82	0.44	+ 0.88	+ 2.44	Do.
64	do	2.57	0.002	1.33	0.06	+ 1.27	+ 1.66	Do.
65	do	1.80	0.005	0.85	0.11	+ 0.74	+ 1.51	Do.

less-concentrated solution had to be used per unit area of crown than the more-concentrated solution, thereby incurring correspondingly greater labor expense, which in this case happened to be the deciding factor in determining the margin of profit and loss, all of the treatments being equally effective at practically the same cost although of different volumes of materials.

It may be seen from Table 20, which gives the results from the same treatments on the pico variety, on the other hand, that the reverse is true; namely, that the greater the amount of "Black leaf 40" in the spray solution used, the smaller the profit obtained. This seems to indicate that the pico variety is more susceptible to the toxic effect of the nicotine-soap solution than the carabao variety. In spraying the pico variety for the blossom-blight hoppers the less-concentrated solution of nicotine-soap should therefore be preferred to attain good results.

SOAPSUD SPRAY

It may be seen from Table 13 that spraying mango trees of both carabao and pico varieties with 0.5 per cent soapsud solution for the control of blossom-blight hoppers, increased on the average the yield of the treated side 4.2 times that of the check or the untreated (Plate 12, figs. 1 and 2), while the treatment with a weaker concentration (0.4 per cent) of the same spray solution yielded seemingly better results, increasing the crop of the treated sides five times that of the unsprayed or the checks (Plate 13, figs. 1 and 2) as shown in Table 14. Analysis of the data shows that this is not the case. Splitting the two varieties apart and computing the total expenses incurred in spraying each carabao tree of 100 square meters crown, the net profit obtained is 26.70 pesos for 0.5 per cent solution as against 10.83 pesos for 0.4 per cent solution (Table 20, series 4 and 5).

These results indicate that spraying for blossom-blight hopper control on carabao mango with 0.5 per cent soapsud would give better returns than spraying with 0.4 per cent soapsud. It may be seen from Table 20, series 4 and 5, which gives the results from the same treatments on the pico variety, that, as in the case of nicotine-soap spray and perhaps for the same reason that pico has a more-delicate inflorescence, the less-concentrated spray solution (0.4 per cent) gave on the average a larger net profit than the more concentrated (0.5 per cent).

SOAPSUD VS. NICOTINE-SOAP

When 0.5 per cent soapsud was tested against Formula 2 of nicotine-soap containing 0.36 per cent soap and 0.1 per cent "Black leaf 40" side by side on the same trees to control the blossom-blight pest, the treatments yielded on the average per 100 square meters of crown 1,550.4 fruits for the former and 1,680 fruits for the latter as against 289.2 fruits for the checks or the untreated (Table 17). It appears, therefore, that while soapsud increased the yield of the treated sides per 100 square meters of crown 5.4 times that of the check, nicotine-soap increased it 5.8 times, indicating that nicotine-soap spray is slightly more effective than soapsud spray at the concentrations above given for the control of blossom-blight hoppers (Plate 14, figs. 1 and 2).

Again, it is shown in Table 18 that when the efficacy of 0.4 per cent soapsud was tested against the efficacy of the same nicotine-soap solution (Formula 2) side by side on the same trees the average yields per 100 square meters of crown were 1,215.6 fruits for the first treatment and 1,623.9 fruits for the second treatment, as against 170.2 fruits for the checks or the untreated. In other words, by virtue of the treatments, soapsud increased the yield 7.1 times, while nicotine-soap increased it 9.5 times that of the check. The nicotine-soap spray evidently has shown again better results than the soapsud spray of less concentration (Plate 15, figs. 1 and 2).

In the third series in which 0.4 per cent soapsud was applied on one side of the crown and a less-concentrated nicotine-soap, Formula 4, containing 0.3 per cent soap and 0.05 per cent "Black leaf 40" on the other, with the middle strip of the crown left untreated as check, the soapsud sides produced on the average slightly better results than the nicotine-soap sides (Plate 16, figs. 1 and 2). As shown in Table 19 the soapsud sides had 1,186.7 fruits (increase, 4.1 times), while the nicotine-soap sides had 1,146.7 fruits (increase, 4 times) per 100 square meters of crown as against 285.4 fruits of the checks.

It is interesting to note in these three series the varied responses of the trees to the treatment. While in the first and second series the treatments increased on the average the yields by 5.6-fold and 8.3-fold, respectively, in the third series the increase was but 4-fold. The reason for this discrepancy cannot possibly be due to the difference in the concentrations of the spray solutions used in as much as, although some variations were made, there was always one basis in common as may be seen by referring to Tables 17, 18, and 19, or to Table 20, series 6, 7, and 8. To what factor then was the variation due? By going over the description of the trees included in the three series, it will be noted that the hopper infestations pertaining thereto were moderate to severe, severe, and moderate, for the first, second, and third series, respectively. Naturally, the greatest damage was suffered by the checks of the second series, followed by the check of the first series, while the checks of the third and last series suffered the least. It is reasonable, therefore, to expect the variation in the corresponding increases in yield accruing from the same or identical treatments. This view seems to afford sufficient grounds for believing that the heavier the hopper infestation, the greater is the increase in yield resulting from spraying. However, there is an exception to this, and that is when heavy or severe infestation occurs as early as the time the inflorescence buds are but 1 to 4 centimeters long, in which case the treated sides may already be severely damaged before any treatment can be applied (Table 21).

This greater increase in the yield in fruits resulting from the treatment of severely infested trees over the checks should not be misconstrued to mean correspondingly larger financial profit in as much as the total average expenses incurred are comparatively higher, being almost twice as much as the first and thrice as much as the third, as shown in Table 20, series 6, 7, and 8.

By converting these increases in yields resulting from the beneficial effects of the different treatments into net profit in terms of pesos and centavos, the following (Table 20, series 6 to 8) are obtained from each carabao tree of 100 square meters crown:

First series: Spraying with 0.5 per cent soapsud, 25.14 as against 17.55 pesos for nicotine-soap, Formula 2.

Second series: Spraying with 0.4 per cent soapsud, 17.41 as against 15.54 pesos for nicotine-soap, Formula 2.

Third series: Spraying with 0.4 per cent soapsud, 19.26 as against 14.92 pesos for nicotine-soap, Formula 4.

The average of the total net profits for these three series, 6, 7, and 8, as shown in Table 20, is 20.60 pesos for the soapsud treatment as against 16 pesos for the nicotine-soap treatment, or a net gain of 4.60 pesos for soapsud over nicotine-soap. It may be seen from the same table, however, that the averages of the total net profits for all the eight series are practically equal; namely, 19.87 pesos for soapsud and 20.97 pesos for nicotine-soap. This should not be taken as the basis for comparison in efficiency in as much as in series 1 to 5 the two spray solution (soapsud and nicotine-soap) were not applied side by side on the same trees, but each was applied side by side with the checks or untreated. Because of the variabilities existing between the producing habits of individual trees even of the same variety, as revealed by many trees observed, some of these series might have been placed on good yielders while others might have been on fair or poor yielders. This might have been the case with series 1, 2, and 3 as compared with series 6, 7, and 8, all of the nicotine-soap series. It may be noted that although treated with the same solution of the same strength, series 2 gave a net profit of 25.76 pesos as against 17.55 and 15.54 pesos for series 6 and 7, respectively.

In the case of the pico variety it is shown in Table 20 that a larger net profit per 100 square meters of crown was realized from soapsud than from nicotine-soap in each and every one of the entire series.

There seems to be sufficient grounds, therefore, to state that, although not as effective as nicotine-soap, soapsud under ordinary conditions is a better spray for the control of the blossom-blight hoppers, principally because it gives, due to its cheapness, a larger net profit on the average, and secondarily because it is practically nontoxic to higher animals, convenient, and readily and safely handled even by inexperienced workers. When the price of mangos is high, however, reaching for instance, two or three times the quotation herein given as generally is the case with an offseason crop, nicotine-soap may prove the better spray to use. The same thing may be said if cost of labor is limited and its cost high, as found in some localities.

SPRAYING TREES WITH SLIGHT INFESTATION OCCURRING LATE AND TREES WITH SEVERE INFESTATION OCCURRING EARLY

In Table 21 is given the comparative yields obtained by spraying with 0.5 per cent soapsud trees with slight infestation occurring late on the one hand, and trees with severe infestation occurring early on the other. Under the column "Yield" it is shown that trees 24, 44, 6, 12, and 45 produced heavy yields on both the treated and the check sides, while trees 60, 61, 64, and 65 produced on the average barely two hundred fruits each on the sprayed sides and fifteen fruits each on the checks. This would seem to indicate that the treatment did not give beneficial effect to the first five trees while the last four showed great response.

These varying reactions exhibited by the trees to the same treatment may perhaps be explained, at least in part, by the time and volume of the hopper infestation that each had during blooming. This phase was discussed at length under the infestation experiment given in Table 6. It is also shown that tree 44 had but slight infestation, which occurred late and might have been so mild as to cause but insignificant damage and hence the very little difference in the yields between the treated and the check; it is also shown on the other hand that tree 24 had slight infestation and yet the treated side produced almost twice as many fruits as the check, indicating that it responded to the treatment. The other reason may perhaps be the difference in the susceptibility or resistance of the individual trees to the hopper infestation. Hence the great contrast shown between the yields of the treated sides and the checks.

By expressing these yields in monetary gross income the first five trees turned out creditably, while the last four showed poorly. When computed for net profit per 100 square meters of crown interesting results were obtained. Trees 44 and 12 gave a net loss of 0.75 and 2.15 pesos, respectively, showing that they suffered little if any damage from the infestation. On the other hand, all the remaining trees yielded insignificant net profits, with the possible exception of tree 24 which had very slight infestation.

Based on the foregoing results, it may be said in a general way that when infestation by blossom-blight hoppers is slight and occurs late, spraying for immediate returns and profit cannot be assured at the price quoted herein, unless such trees are known to be highly susceptible to the ravages of the infestation. Tree 24 seems to fall under this classification.

The same thing may be said when the infestation is severe and occurs early. If the tree thus infested happens to be fairly highly resistant to the infestation, which seems to be the case with some trees under observation (Plate 17, figs. 1 and 2), spraying would seem to be of little use, because without it many fruits will set and develop to maturity just the same. If the tree happens to be susceptible, spraying may help in saving some fruits, but the margin of profit in such an operation is generally so meager that it would not pay for the trouble and effort, as in the preceding case.

Therefore, in spraying for the control of the blossom-blight pest the first thing to do is to examine the trees for the infestation. This is better accomplished while the inflorescence buds are only a few centimeters long and before the flower buds begin to show signs of opening. If there be on the average two or more adult hoppers of either species per panicle, spraying should be considered absolutely necessary unless the flower buds already are discolored and damaged at the time due to the early occurrence of the infestation. On the other hand, if the average infestation per panicle is less and occurs when the inflorescences already are fairly developed, spraying may be of no avail except for reducing the sources of infestation for noninfested trees. Knowledge of why and when to spray is obviously of prime necessity to successful spraying. Similarly, keen observation of the habits and idiosyncrasies of the individual mango trees may, perhaps, help in avoiding unnecessary and wasteful operations.

OTHER FACTORS GENERALLY ASSOCIATED WITH BLOSSOM-BLIGHT IN CAUSING MANGO FAILURE

Together with the blossom-blight hoppers there are several factors of minor importance generally associated with mango failure, principal among which are the anthracnose disease caused by the *Gloeosporium* stage of *Glomerella cingulata* (Stonem.) S. and v. S. and the tip-borer pest caused by *Chlumetia transversa* Walker.

THE ANTHRACNOSE

The anthracnose disease, caused by a fungus known as *Glomerella cingulata* (Stonem.) S. and v. S., as reported by Palo(4) is not as serious a factor in mango failure as was thought at first. It may, however, occur in an alarming proportion and cause serious damage to the crop when favorable weather conditions obtain. Plenty of moisture and warm atmosphere or high humidity seem to be essential for its proper development. Owing to the fact that, unless the trees are forced to bloom by smudging during the more or less wet months of October, November, and December, the flowering season for mangos by nature coin-

TABLE 22.—*Weather observation from January to June, 1932.*[a]

Date.	Observations.	Total rain in each month.	
1932		*in.*	*mm.*
Jan. 13	Shower shortly after midday	0.04	1.1
Feb. 1	Shower in the afternoon		
Feb. 12	do		
Feb. 28	Shower for about 15 minutes at about midnight	0.03	0.9
Mar. 16	Shower at night		
Mar 23	Shower for 2 hours before midday		
Mar. 29	Shower for 15 minutes shortly after midday	0.21	5.4
Apr. 22	Slight shower at night	0.02	0.5
May 12	Shower for about 1 hour before midday and continuous shower at night		
May 13	Rain for 30 minutes in the afternoon and alternate rain and shower at night		
May 14	Shower for 30 minutes before midday		
May 15	Rain for 3 hours in the afternoon		
May 23	Shower for 30 minutes shortly after midday and rain for 1 hour early in the evening		
May 26	Rain for about 1 hour in the afternoon		
May 28	Shower at night		
May 29	Rain for 25 minutes in the afternoon		
May 31	Rain in the morning and at night	8.49	215.6
June 1	Shower at night for about 10 minutes		
June 2	Rain for about 30 minutes in the afternoon		
June 3	Rain for about 25 minutes in the afternoon		
June 5	Shower for about 5 minutes in the morning		
June 6	Rain for 40 minutes in the afternoon		
June 7	Shower for 10 minutes in the afternoon		
June 8	Rain for 15 minutes in the morning and for about 1 hour in the afternoon		
June 9	Shower for 15 minutes before midday and for about 1 hour in the afternoon		
June 10	Shower in the afternoon		
June 11	Continuous rain and showers the whole day		
June 12	Showers in the morning and in the afternoon		
June 13	Shower for 25 minutes shortly after midday		
June 14	Rain for 30 minutes in the afternoon		
June 15	Rain for 25 minutes early in the day		
June 16	Shower for 35 minutes early in the evening		
June 17	Rain for 1 hour shortly after midday		
June 20	Shower for 20 minutes in the afternoon		
June 23	Shower for 10 minutes early in the day		
June 24	Rain for 30 minutes early in the evening		
June 26	Rain and showers for 4 hours in the morning		
June 28	Shower for 4 hours in late afternoon and evening		
June 29	Rain for 30 minutes in the afternoon and for nearly 2 hours in the evening		
June 30	Rain for 45 minutes in the morning and 25 minutes in late afternoon	8.40	213.6

[a] These figures represent the total rainfall at the Alabang rice experiment station and were obtained through the kindness of officials of the Philippine Weather Bureau.

cides with the dry season or months of practically no rain, from January to April, a severe occurrence of this disease is possible but not probable. In the summer of 1932, in spite of the occasional rain that fell in Muntinlupa and vicinity, not a single case of anthracnose infection was observed. Towards the end of May, 1932, soon after a week of more or less continuous rain and shower beginning on the 12th, a serious outbreak of the disease was noted on a number of mango trees flowering late in the season and having the young fruits just starting to set.

In view of the foregoing observations it would seem justifiable to state in a general way that unless there is a more or less continuous rainfall for several days, which is rather unusual in January to April when the mangos are in flower, no fear should be entertained of a severe infection by anthracnose disease in Muntinlupa and vicinity or in any other locality having similar or identical climatic conditions (Table 22). Its control or prevention, when likely to occur in an alarming proportion is, however, worthy of thoughtful consideration. The necessity for this may perhaps be felt the more when smudging is resorted to in forcing the trees to flower during the off-season, which is generally attended by frequent rainfalls.

It might be mentioned in this connection that the results of preliminary experiments, coupled with observational facts, tend to disprove the common belief that an occasional rainfall when mangos are in flower is synonymous with mango failure. If rainfall is truly and directly harmful to the mango flowers, the average crop per tree produced from flowers during May when there is abundant rain must necessarily be reduced, but actual observations in the field indicate the contrary. It may become inimical, however, under certain conditions, as in the presence of anthracnose disease which is favored by moisture. Owing perhaps to the microscopic nature of the organism causing this disease which occurs invariably and only in the presence of abundant moisture supplied by a more or less continuous rain and shower for several days at least, casual observers are led to believe that the resulting damage to the mango crop is directly and wholly due to the rain which favors the rice crop on the other hand. Rain or abundant moisture in the absence of the pathogenic organism appears, therefore, as harmless to the mango crop as the anthracnose disease in the absence of adequate moisture for its proper development.

THE TIP-BORER

The "tip-borer" pest, the larva of the moth *Chlumetia transversa* Walker, is another factor to consider in solving the problem of mango failure, as it is more or less constantly associated with blossom-blight hoppers. The fact that the larva of this insect pest attacks the mango generally by entering at or about the apices of the inflorescence, tunneling its way into the basal part, thereby forming a cavity in it and causing the tops of the affected parts to shrivel and die, but often leaving the lateral branches and flower buds apparently unharmed, may explain why, according to field observations, moderate infestation by this pest is of no grave concern. However, when it occurs with severity the necessity for studying means for its control may become obvious.

LIGHT-TRAPPING EXPERIMENT

Light trapping has been practiced since time immemorial as a means of catching nocturnal lepidopterous insect pests that are positively phototropic. It is not, however, as popular as either spraying or dusting. It is certain, of course, that in the majority of cases profits are forthcoming in less time and with little expense by either spraying or dusting, but there are times when light trapping may be resorted to with advantage. In the present case, should the hoppers prove to be light loving, light trapping may, perhaps, be used to advantage in places where inadequate water supply is a handicap to spraying operations. It is for this reason that the following preliminary experiment was conducted.

Each of two lanterns was placed in a basin of water to which a little kerosene was added. Each basin was located under a mango tree infested by a moderate number of adult hoppers, preponderantly *I. clypealis*, each basin being placed on a flat surface of a lateral branch about 2 meters from the ground. At about 6 p. m. May 5, 1932, the lanterns were lighted and left in place overnight. The following morning each basin was examined for the insects caught, particularly blossom-blight hoppers. This was repeated under the same trees on five different nights, when the moon appeared at different phases; namely, May 20, 27, 31, and June 4, 1932. The results are given in Table 23.

The largest catch was May 5, when there was no moon; while the smallest catch was May 20, when there was a full moon. The total catch of both *Idiocerus niveosparsus* and

TABLE 23.—*Results of light trapping.*

Date observed.	Phase of the moon.	Caught in two traps.	
		Idiocerus clypealis.	*Idiocerus niveosparsus.*
1932			
May 5	No moon	215	1,050
May 20	Full moon	40	36
May 27	Last quarter	174	250
May 31	Half quarter	283	269
June 4	New moon	324	422
Total catch		1,036	2,027

I. clypealis is as follows: 1,265 adults May 5, when there was no moon; 76 adults May 20, when there was a full moon; 424 adults May 27, when the moon was at last quarter; 552 adults May 31, when the moon was at half quarter; and 746 adults June 4, when there was a new moon and the night was practically as dark as when there was no moon. The total catch of each species was 1,036 for *I. clypealis* and 2,027 for *I. niveosparsus*. Numerous other insects were also trapped.

These results would seem to indicate that, like many other insect pests, *Idiocerus clypealis* and *I. niveosparsus*, particularly the latter, are attracted by light although not strongly positively phototropic; that the darker the night, the better for the trapping; and that *I. niveosparsus* is better attracted by light or more positively phototropic than *I. clypealis*. This is economically beneficial because, as observed in the field and proved by experiment, *I. niveosparsus* is the more destructive and the more persistent of the two species.

Finally, light trapping, if used judiciously and early enough to get the adult hoppers before they have an opportunity to lay eggs in the inflorescences, may help reduce materially the damage caused by them, particularly the large species, *I. niveosparsus*. It may prove useful especially for isolated trees or groves where there is little chance of reinfestation from the neighborhood, and in places where lack of water supply is a handicap to spraying operations.

SUMMARY AND CONCLUSION

1. Blossom-blight is the most destructive insect pest of the mango, *Mangifera indica* Linnæus, in the Philippines. It is caused by two species of leaf-hoppers, *Idiocerus niveosparsus*

Léthierry and *I. clypealis* Léthierry. It apparently attacks with equal severity the carabao, pico, and señora varieties as well as many other unidentified hybrids. The pahutan variety of *Mangifera altissima* Blanco is also infested, but the crop does not seem to suffer at all.

2. It was found in Cavite, Rizal, Bulacan, Batangas, Laguna, Bataan, Pampanga, Tarlac, Zambales, Nueva Ecija, and Pangasinan Provinces, causing on the average 75.32 per cent damage to the mango crop in the first three provinces. There are indications, therefore, that the bright future of mango, admittedly the premier dessert fruit of the Philippines, is being seriously threatened by this noxious pest.

3. Whether this pest is indigenous to the Islands or not is unknown.

4. The percentage of perfect flowers does not seem to be in any way related to mango failure. This is based on the fact that the carabao mango was found to have on the average 45.2 per cent perfect flowers as against 25.3 per cent of the pico variety, and yet practically they are equally productive; the former, owing to its superior qualities and larger size, commands a better price and therefore gives a greater net profit from the treatment.

5. The hoppers may damage the crop in two ways. First, owing to the heaviness of egg-laying, physical injury is inflicted on the flower stems as well as the individual flower buds, thereby causing them to wither and drop. Second, the nymphs which hatch in large numbers, crowd together among the florets and with their proboscis pierce the tissues of the flower stems and draw the sap. Most of the sap thus sucked is, however, excreted after a certain amount of digestion as droplets of sticky sweetish fluid commonly known as honeydew. This gives rise to the sooty mold that causes partial blackening of the infested trees.

6. In severe cases of infestation it is not unusual to find all of the inflorescences withered and the young fruits conspicuous by their absence, thereby causing a total loss of the crop.

7. The large species of blossom-blight hopper is *Idiocerus niveosparsus* Léthierry. It is wedge-shaped, cinnamon-drab, and measures 3.8 to 4 millimeters long.

8. *Idiocerus niveosparsus* has five nymphal stages, covering a period of about seven and one-half days. The nymphs live on the flower flushes during the flowering season and on the leaf flushes during the offseason. The eggs are cigar-shaped, 1.2

millimeters long and 0.2 millimeter thick. They are laid in the flower stems and flower buds during the blooming season, and in the midribs of tender leaves generally on the lower surface during the offseason. They hatch in a little over four days, so that the total span of its life from the laying of the eggs to the emergence of the adults is about eleven and one-half days.

9. There are, on the other hand, but four nymphal stages of *Idiocerus clypealis* covering about nine and one-half days. The nymphs live exclusively on the inflorescences. The eggs are cigar-shaped 0.75 millimeter long and 0.1 millimeter thick. They are laid exclusively in the flower buds, which may explain why no copulation of this species takes place during the offseason or as soon as the flowers have started to wither. They hatch in about four and one-half days, so that the life cycle from the laying of the eggs until the emergence of the adults is about fourteen days.

10. The adults of both species of blossom-blight hoppers seem to be most active when the mangos are in flower; that is, from January to April, or perhaps even as early as October to December when the trees are forced to bloom by smudging. Beginning the latter part of May or early in June when there are no more flowers, the small species, *Idiocerus clypealis,* may be found living, at least in part, on various plants, while the large species, *Idiocerus niveosparsus,* apparently remains all the year round on mangos. Unlike the small species the large species was found to lay eggs, although to a limited extent, even during the offseason whenever there is suitable food material in the form of leaf flushes.

11. A fungous parasite (perhaps *Isaria* sp.) was found attacking and killing the adults of *Idiocerus clypealis,* pasting them on the nether side of the leaves. There are, besides, several predators (ladybird beetles, ants, and spiders) that feed on the nymphs and eggs of both species. With all this, there seems to be a possibility of reducing the damage caused by the hoppers, by biological means.

12. The large species, *Idiocerus niveosparsus,* proved to be more destructive than the smaller species, *I. clypealis,* but its superior destructiveness is often overshadowed by that of the latter due to its overwhelming preponderance.

13. Any infestation having on the average two adults or more per panicle, whether by *Idiocerus clypealis* or *I. niveosparsus* or

both, needs spraying. Lighter infestation, unless by the larger species or unless occurring as early as when the inflorescence buds are still developing, may not need spraying except for the purpose of reducing the source of infestation for noninfested trees.

14. Of the nicotine-soap solution of various concentrations tried Formula 1, containing 0.36 per cent soap and 0.12 per cent "Black leaf 40" (nicotine sulphate), proved to be the most effective and the most economical for spraying the carabao variety. For the pico variety, which seems to possess a more-delicate blossom, Formula 4, containing 0.3 per cent soap and 0.05 per cent "Black leaf 40," showed the best results.

15. As a contact insecticide, soap was found to be more effective than "Black leaf 40," indicating that it is the main active principle in nicotine-soap solution. The right combination of the two (Formula 1) proved, however, to be more effective than either one of the same strength taken individually.

16. The Chinese yellow laundry soap, followed closely by the Señorita soap and resin soap, proved to be the most effective and the cheapest of the brands tested.

17. Soapsud of 0.5 per cent concentration was found more effective and economical than soapsud of 0.4 per cent concentration for spraying the carabao variety, while the reverse proved to be true for the pico variety.

18. Spraying with 0.5 per cent soapsud increased on the average the yield of the carabao variety four and seven-tenths times that of the untreated or the check (813.2 fruits of the treated vs. 172.4 fruits of the check) at a total expense of 0.00204 peso per fruit; while spraying the same with nicotine-soap, Formula 1, increased the yield five times that of the check (871.5 fruits of the treated vs. 172.4 fruits of the check) at a total expense of 0.00666 peso per fruit.

At this increase of the yield and cost of spraying a fruit and at a selling price of 3 pesos a kaing of fruits, the net profit obtained from a carabao tree of 100 square meters of crown was 20.60 pesos for the soapsud treatment and 16 pesos for the nicotine-soap treatment, or a difference of 4.60 pesos in favor of soap. The market price of the crop will, of course, invariably affect the net gain.

19. Stress is placed upon the right time of spraying and the thoroughness of application. Haphazard treatments can only reap a crop of failure and consequently unnecessary expense.

20. Spraying trees with very slight infestation occurring late, trees with severe infestation occurring early, and trees known to have an exceptionally high degree of resistance to the blossom-blight attack, is not advisable unless for the purpose of reducing the source of new infestation.

21. The old common belief that the advent of rainfall when mangos are in flower is synonymous with mango failure is explained. The rain is destructive to the mango crop in that moisture favors the anthracnose disease, *Glomerella cingulata* (Stonem.) S. and v. S., which attacks and kills the flowers as well as the young tender fruits.

22. In places where lack of water supply is a handicap to spraying operation, light trapping as a means of minimizing the ravages caused by blossom-blight hoppers, particularly the large species, *Idiocerus niveosparsus* Léthierry, which proved to be fairly well attracted to light, or positively phototropic, may be used to advantage. This method may prove especially useful to isolated trees or groves where there is a little chance of reinfestation from the neighborhood.

23. Crossing the carabao mango with the pahutan so as to obtain a hybrid possessing the desirable qualities of the carabao fruit and the exceptional resistance of the pahutan to the blossom-blight pest may offer an opportunity to evolve a more or less permanent control for the pest.

24. Obtaining the scions for grafting or budding purposes from the carabao trees that have persistently shown a high degree of resistance to the pest would seem to be another means that might prove helpful or effective in minimizing the ravages of the pest.

25. The results herein presented, covering but one season's observation and experimentation, are not meant to be taken as so final and conclusive as to be applicable to other seasons. Further investigation of the subject at different seasons may bring about some slight modification of the views expressed herein; but there are some facts discovered that lead to advice which, if followed, will help the mango growers save much of their crop.

RECOMMENDATIONS

On the basis of the foregoing observations and experiments the writers recommend the following control measures.

SPRAYING[5]

In view of the fact that under field conditions the hopper infestation varies to a certain extent as to severity and age of the inflorescences when it occurs, which, together with the individual characteristic of the mango trees, constitutes the factor that determines the advisability or not of spraying for immediate financial profit, it is necessary first to examine carefully the trees for the infestation. This should be accomplished before the flower buds show signs of opening, or about ten days after the emergence of the inflorescence buds. During egg-laying the adult hoppers are quite tame and may be observed on the flowers without difficulty.

When there are on the average two or more adults of either species or both per panicle, spraying should be considered absolutely necessary unless the flower buds are already discolored and damaged at the time resulting from the early occurrence of the infestation, or unless the particular tree so infested is known to be of the highly resistant type; that is, one which produces a good crop every time it blossoms profusely, the heavy hopper infestation notwithstanding. On the other hand, if the hopper infestation per panicle is less and occurring when the inflorescences are pretty well developed or beginning to open, spraying may be of no avail unless for the purpose of reducing the source of infestation for non-infested trees. Knowledge of why and when to spray is obviously of prime necessity to successful spraying. Similarly, keen observation of the habits and idiosyncrasies of the individual mango trees may help to avoid unnecessary and wasteful operations.

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[5] The spray. solutions may be prepared in the following manner:

To make the stock solution of 0.5 per cent soapsud for 100 liters of the spray solution, dissolve 500 grams of Chinese yellow laundry soap sliced into small pieces in 10 liters of hot water (70° to 80° C.) in a gasoline or petroleum can, stirring the water once in a while. As soon as all particles of soap are dissolved dilute the solution with enough water in a big container (50-gallon barrel) to make 100 liters of 0.5 per cent soapsud spray solution ready for use.

For 0.4 per cent soapsud, follow exactly the same procedure, but use 400 grams of soap for the same amount of spray solution.

Nicotine-soap, Formula 1, containing 0.36 per cent soap and 0.12 per cent "Black leaf 40" (nicotine sulphate), may be prepared in the following manner: To prepare the stock solution for 100 liters of spray solution, dissolve 360 grams of Chinese yellow laundry soap, then add to the solution in a large container (50-gallon barrel) 120 cubic centimeters of "Black leaf 40" and dilute it with enough water to make 100 liters of Formula 1 nicotine-soap spray solution ready for use.

Nicotine-soap, Formula 4, containing 0.3 per cent soap and 0.05 per cent "Black leaf 40," may be prepared by following exactly the same procedure as the preceding but using only 300 grams of soap and 50 cubic centimeters of "Black leaf 40" for the same amount of the spray solution, or 100 liters.

The approximate time and volume of infestation once determined, the next thing to do is to examine the inflorescences for the presence of nymphs or young wingless hoppers from first to third stages appearing generally thirteen to fourteen days after the emergence of the inflorescences, or a day or two after the flower buds have started opening. This may be accomplished easily by holding the base of the panicle in the hand and agitating it for a half minute or so. The nymphs may be seen moving down the flower stems. Do this on several panicles so as to gain a fair idea of the species present and severity of infestation.

Use 0.5 per cent soapsud for the carabao variety and 0.4 per cent soapsud for the pico variety, which evidently possesses a more-delicate inflorescence and hence is susceptible to the toxic effect of the spray. Apply the spray with thoroughness, using Gould's or Demming's hand spray pump, or if available, a power spray pump provided with 10 to 20 meters of rubber hose tied to a bamboo rod. If the trees are tall, use a bamboo ladder with props in spraying the tops, directing the solution against the flowers at all angles to ensure the complete wetting of all the nymphs in the inflorescences, upon which greatly depends the efficacy of the treatment. Repeat the spraying four times at two-day intervals if the large species, *Idiocerus niveosparsus* Léthierry, or both species are present. If the small species, *I. clypealis* Léthierry, is present alone, repeat the spraying only three times at three-day intervals, wetting not only the inflorescences but also the lower surfaces of the leaves just below the panicles where most of the largest wingless hoppers or nymphs generally hide prior to their last molting. After each application the inflorescences should be examined to determine how thoroughly the spray had been applied as may be indicated by the amount of kill. This will guide the operator in his next move.

Reinfestation by the large species of hoppers, *Idiocerus niveosparsus* Léthierry, may increase the number of sprayings. This usually occurs after the flowers have withered and the young fruits are set.

When there are indications that the price of mangos will be high, as for instance about 10 pesos per kaing, the use of nicotine-soap spray may prove as economical as, if not more so than, the soapsud spray, and hence preferable. The same thing may be said in places where the cost of labor is high and the right kind of soap not readily available.

For spraying the carabao variety use Formula 1, containing 0.36 per cent soap and 0.12 per cent "Black leaf 40" (nicotine sulphate); for spraying the pico variety use Formula 4, containing 0.3 per cent soap and 0.05 per cent "Black leaf 40," following in either case the same procedure as that given for soapsud.

Stress is placed upon the importance of arousing community spirit in pushing the campaign against this noxious pest to a successful end. Unless each grower adopts the necessary steps to stamp out and free his grove from the pest, the desired goal will be difficult to attain.

LIGHT TRAPPING

In places where inadequate water supply is a handicap to spraying operation, light trapping as a means of minimizing the ravages caused by the hoppers, particularly the larger species, *Idiocerus niveosparsus* Léthierry, which proves to be fairly well attracted to light, or positively phototropic, may be used to advantage. This method may prove especially useful to isolated trees or groves where there is little chance of reinfestation from the neighborhood.

The trap may be set by placing a lighted lantern in the middle of a large basin with water to which a little kerosene has been added, and placing the basin on a stand 1 to 2 meters above the ground under the infested tree early in the evening when there is no moon or when it is practically dark the whole night and leaving it there till morning. Strain out the catch every day before setting out the trap anew. Do this for about seven to ten days beginning the last quarter, to coincide with dark nights and with smudging, or about a week before the inflorescence buds come out so as to prevent the hoppers from laying eggs thereon.

It should be borne in mind that light trapping during bright moonlight is as ineffective as light trapping after the eggs have been laid.

BREEDING AND SELECTION

The advisability of breeding for resistance should be given the necessary stimulus and support. Crossing the carabao mango with the pahutan so as to obtain a hybrid possessing both the desirable qualities of the carabao fruit and the resistance of the pahutan to the pest, may offer an opportunity to evolve a more or less permanent control for the pest. Of course, this may require several years before any definite result is obtained owing to the late-maturing characteristic of the mangos; but the delay in time is nothing compared with the lasting benefits that may accrue therefrom.

In grafting and budding, the use of scions from the carabao trees which have persistently shown a high degree of resistance to this noxious pest may prove helpful in minimizing its ravages.

The modern conception of disease and pest control hinges on this mode of attack.

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ILLUSTRATIONS

PLATE 1

FIG. 1. A flower bud of carabao mango showing six eggs in three pairs, of *Idiocerus clypealis*. The bud was purposely opened to illustrate the position of the eggs as they are laid between the sepals and petals; about × 5.
2. *Idiocerus clypealis*, first nymphal stage, about × 5.
3. *Idiocerus clypealis*, second nymphal stage, about × 5.
4. *Idiocerus clypealis*, third nymphal stage, about × 5.
5. *Idiocerus clypealis*, fourth nymphal stage, about × 5.
6. *Idiocerus clypealis*, adult and last stage, about × 5.
7. A tip of a fully developed carabao mango inflorescence showing infestation by both species of the hoppers. Note the presence of *Idiocerus clypealis* and *Idiocerus niveosparsus* of different stages; about × 1.
8. A longitudinal section of a flower stem showing a couple of *Idiocerus niveosparsus* eggs in a natural position; about × 5.
9. *Idiocerus niveosparsus*, first nymphal stage, about × 5.
10. *Idiocerus niveosparsus*, second nymphal stage, about × 5.
11. *Idiocerus niveosparsus*, third nymphal stage, about × 5.
12. *Idiocerus niveosparsus*, fourth nymphal stage, about × 5.
13. *Idiocerus niveosparsus*, fifth nymphal stage, about × 5.
14. *Idiocerus niveosparsus*, adult and last stage, about × 5. (Colored drawings by M. Ligaya.)

PLATE 2

FIG. 1. A fully developed inflorescence of carabao mango free from the blossom-blight infestation; about × 0.2. (Photograph by V. F. Ferrer.)
2. A cluster of carabao mango inflorescences representing a typical specimen of the mango blossom-blight pest and showing complete destruction resulting from severe infestation. Note the sooty appearance of the leaves owing to the growth of mold on the honey-dew excreted by the hoppers; about × 0.2. (Photograph by V. F. Ferrer.)

PLATE 3

FIG. 1. A five-day-old mango inflorescence bud showing early infestation by the hoppers. Note the adults of *Idiocerus clypealis* presumably laying eggs in the flower buds; about × 0.8. (Photograph by F. B. Serrano.)

FIG. 2. A group of carabao mango inflorescences of different stages of development showing early infestation by the hoppers; left, the stage at which most of the infestation takes place; middle, the stage at which some infestation takes place; and right, the stage at which very little infestation takes place; about × 1. (Photograph by C. S. Angbengco.)

PLATE 4

FIG. 1. A pico mango inflorescence showing more or less complete destruction of the flowers resulting from early infestation by both species. Note the presence of the nymphs of various stages as well as the growth of the sooty mold on the surface of the leaf on the left side; about × 0.8. (Photograph by V. F. Ferrer.)

2. A carabao mango inflorescence showing an advanced stage of severe infestation by both species. Note four young fruits that survived and might have developed to maturity. The more or less complete blackened appearance of the leaves on account of the abundant growth of the mold on the honey-dew is a sure index to the heaviness of the hopper infestation; about × 0.2. (Photograph by V. F. Ferrer.)

PLATE 5

FIG. 1. A pico mango inflorescence severely infested by *Idiocerus niveosparsus.* Note the nymphs of different stages on the flower stems; about × 0.8. (Photograph by F. B. Serrano.)

2. A carabao mango inflorescence severely infested by *Idiocerus niveosparsus.* Note the nymphs of different stages on the flower stems; about × 0.8. (Photograph by F. B. Serrano.)

PLATE 6

FIG. 1. A carabao mango inflorescence bud just beginning to open. No hopper infestation has been observed to take place earlier than and up to this stage of development; about × 1. (Photograph by V. F. Ferrer.)

2. A partial view of a pico tree showing paper bags and celluloid cylinders inclosing young inflorescence buds for the study on the life history of *Idiocerus clypealis* and *Idiocerus niveosparsus;* about × 0.025. (Photograph by F. B. Serrano.)

PLATE 7

FIG. 1. A new leaf flush of carabao mango showing the exuviæ of *Idiocerus clypealis.* Note that practically all face toward the bases of the leaves; about × 0.5. (Photograph by C. S. Angbengco.)

2. A much enlarged leaf of fig. 1 to show better the exuviæ and the newly molted alults; about × 1. (Photograph by C. S. Angbengco.)

PLATE 8

FIG. 1. Three carabao mango leaves showing dead adult *Idiocerus clypealis* resulting from parasitism by a fungous parasite. Note creeping mycelial growth of the fungus covering and pasting the hoppers fast onto the nether side of the leaves; about × 1.2. (Photograph by C. S. Angbengco.)

2. Pieces of the leaves of various plants on which adults of *Idiocerus clypealis* are shown to be parasitized by the same fungus as in fig. 1; about × 1. (Photograph by C. S. Angbengco.)
    - *a*, Mango, *Mangifera indica* Linn.
    - *b*, Tampoy, *Eugenia jambos* Linn.
    - *c*, Chinese litchi, *Litchi sinensis* Sonn.
    - *d*, Gumamela, *Hibiscus rosasinensis* Linn.
    - *e*, Guayabano, *Anona muricata* Linn.
    - *f*, Achuete, *Bixa orellana* Linn.
    - *g*, Jackfruit, *Artocarpus integra* (Thunb.) Merr.
    - *h*, Breadfruit, *Artocarpus communis* Forst.
    - *i*, Calamunding, *Citrus mitis* Blanco.
    - *j*, Lucban, *Citrus decumana* Murr.

PLATE 9

FIG. 1. A close-up view of two celluloid cylinders showing inclosures of carabao mango inflorescences used for artificial infestation experiments; about × $\frac{1}{8}$. (Photograph by F. B. Serrano.)

2. A group of celluloid cylinders with inclosures of carabao mango inflorescences artificially infested by *Idiocerus clypealis*, as given in Table 7, series 3; about × $\frac{1}{7}$. (Photograph by C. S. Angbengco.)
    - *a*, Showing complete destruction resulting from infestation by ten adults. No fruit.
    - *b*, Showing practically complete destruction resulting from infestation by five adults. Only one fruit.
    - *c*, Showing partial destruction resulting from infestation by two adults. Five young fruits.
    - *d*, Showing the check with many fruits resulting from non-infestation.

PLATE 10

FIG. 1. A blooming pico tree about 15 meters high being sprayed by four men with two hand spray pumps. Note one of the operators on top of a 9-meter ladder with props. This is a demonstration of how tall trees can be sprayed for blossom-blight control. Note pump below the ladder with its nozzle pointing against the tip of the panicle which is a sure way of wetting all the parts of the inflorescence; about × $\frac{1}{100}$. (Photograph by V. F. Ferrer.)

FIG. 2. A close-up view of fig. 1, to better illustrate the way spraying should be done. Note volume of solution striking the flowers directly and dripping therefrom, indicating complete and thorough application; about × 1/25. (Photograph by V. F. Ferrer.)

PLATE 11

FIG. 1. A carabao tree sprayed with nicotine-soap, Formula 1, on the left side, leaving the right side untreated as check. Note difference in the number of fruits that matured on each side; about × 1/40. (Photograph by F. B. Serrano.)

2. As in fig. 1, but with the entire crown sprayed with nicotine-soap, Formula 2; about × 1/50. (Photograph by F. B. Serrano.)

PLATE 12

FIG. 1. A pico tree sprayed with 0.5 per cent soapsud on the left side, leaving the right side unsprayed as check; about × 1/60. (Photograph by F. B. Serrano.)

2. A carabao tree with the entire crown sprayed with 0.5 per cent soapsud; about × 1/80. (Photograph by F. B. Serrano.)

PLATE 13

FIG. 1. A pico tree sprayed with 0.4 per cent soapsud on the left side, leaving the right side unsprayed as check; about × 1/80. (Photograph by F. B. Serrano.)

2. A señora tree with the entire crown sprayed with 0.4 per cent soapsud; about 1/70. (Photograph by V. F. Ferrer.)

PLATE 14

FIG. 1. A carabao tree with the left side sprayed with 0.5 per cent soapsud and the right side sprayed with nicotine-soap, Formula 2; about × 1/40. (Photograph by C. S. Angbengco.)

2. As in fig. 1; about × 1/70. (Photograph by C. S. Angbengco.)

PLATE 15

FIG. 1. A carabao tree with the left side sprayed with 0.4 per cent soapsud and the right side sprayed with nicotine-soap, Formula 2; about × 1/65. (Photograph by F. B. Serrano.)

2. A carabao tree not sprayed as check; about × 1/65. (Photograph by F. B. Serrano.)

PLATE 16

FIG. 1. A carabao tree with the left side sprayed with 0.4 per cent soapsud; the middle part not sprayed as check, and the right side sprayed with nicotine-soap, Formula 4. Note difference in the number of fruits at setting; about × 1/25. (Photograph by F. B. Serrano.)

FIG. 2. A carabao tree treated as in fig. 1. Note abundance of matured fruits on both sides and their scarcity at the middle; about × 1/75. (Photograph by F. B. Serrano.)

PLATE 17

FIG. 1. A panicle of a carabao mango showing many young fruits borne in spite of the moderate to severe infestation by the blossom-blight pest; about × ½. (Photograph by V. F. Ferrer.)

2. A carabao tree showing a fairly heavy crop in spite of the moderate to severe infestation by the blossom-blight pest. This would appear to be possessed of some degree of resistance to infestation; about × 1/75. (Photograph by F. B. Serrano.)

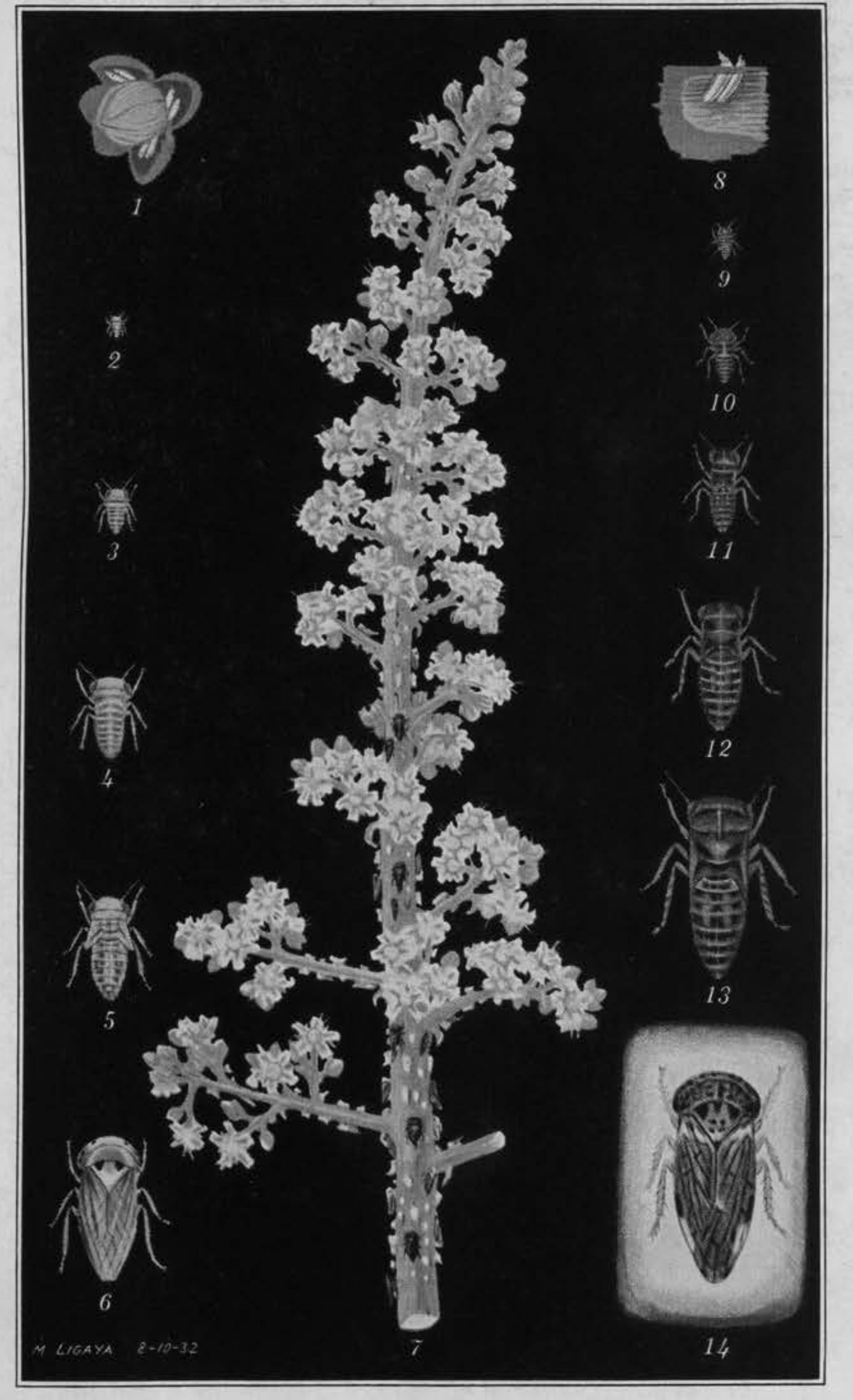
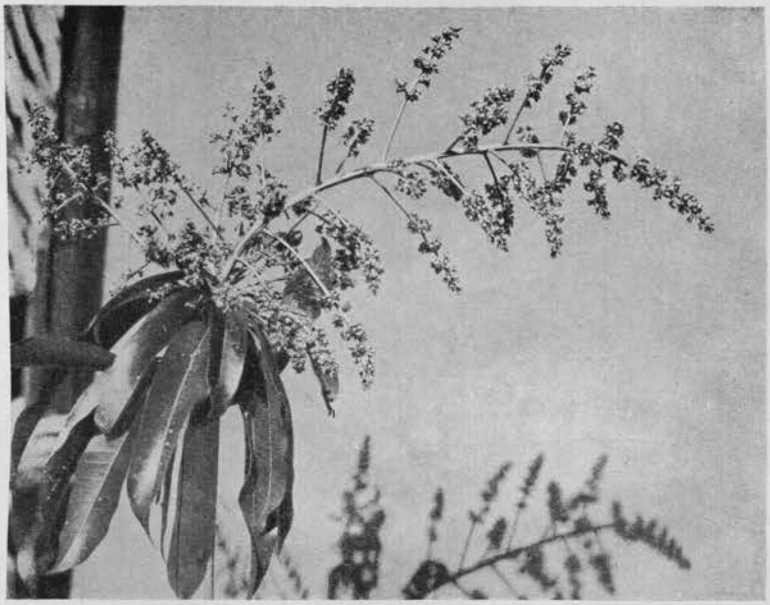


PLATE 1.



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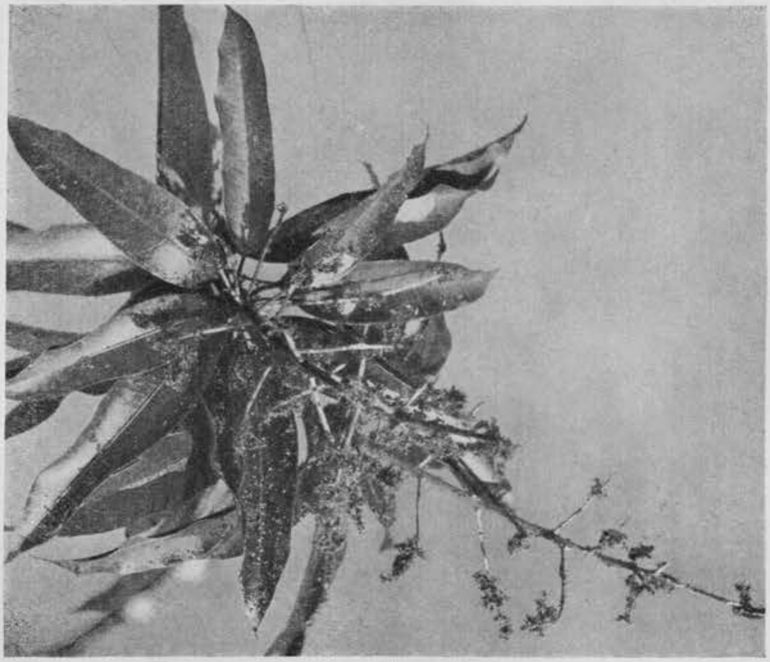

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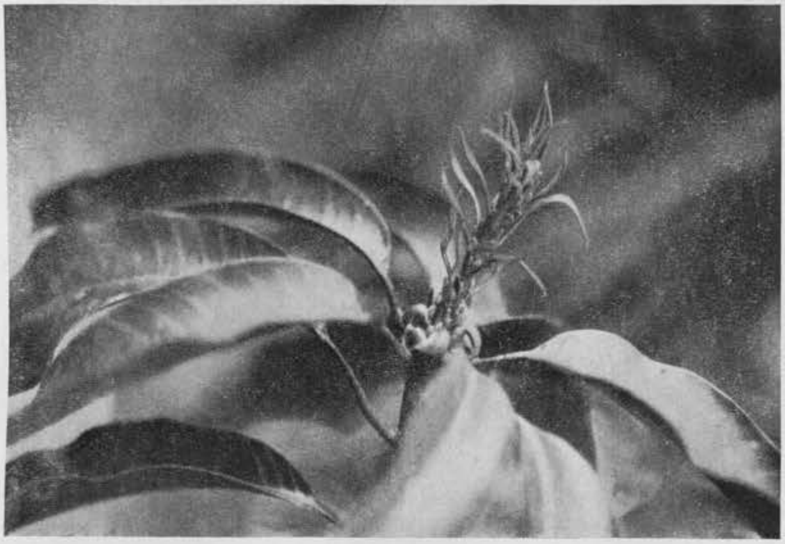
PLATE 2.



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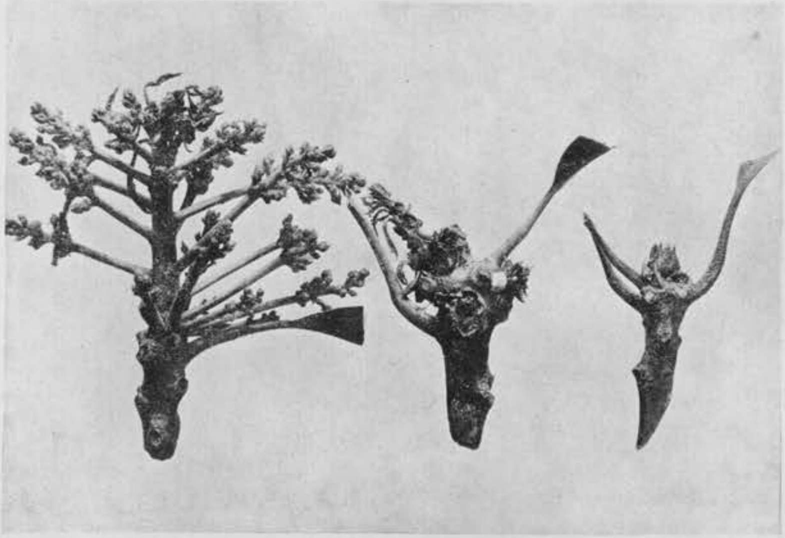

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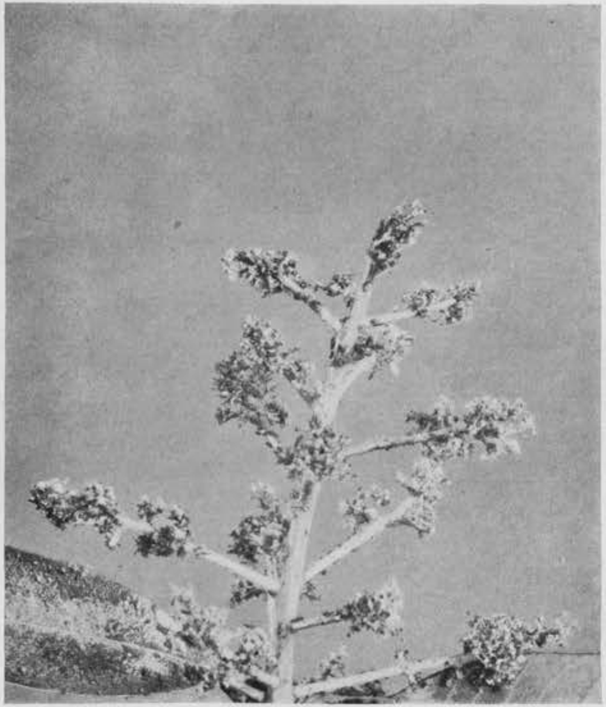

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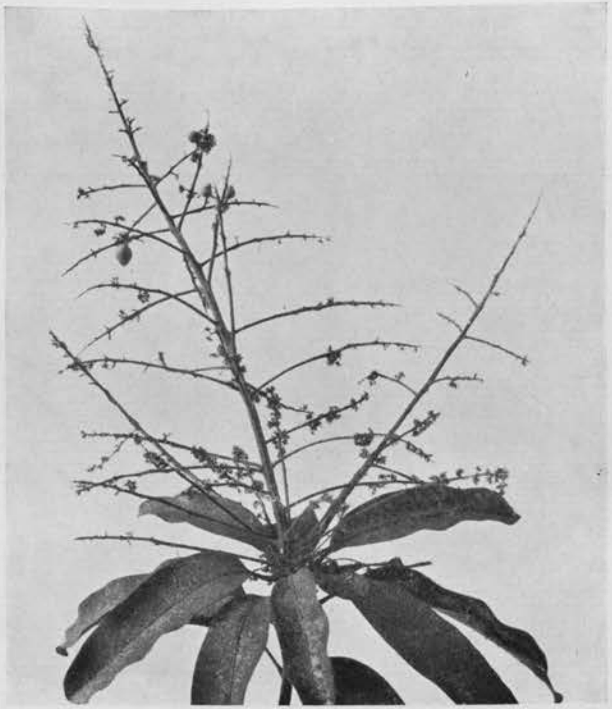

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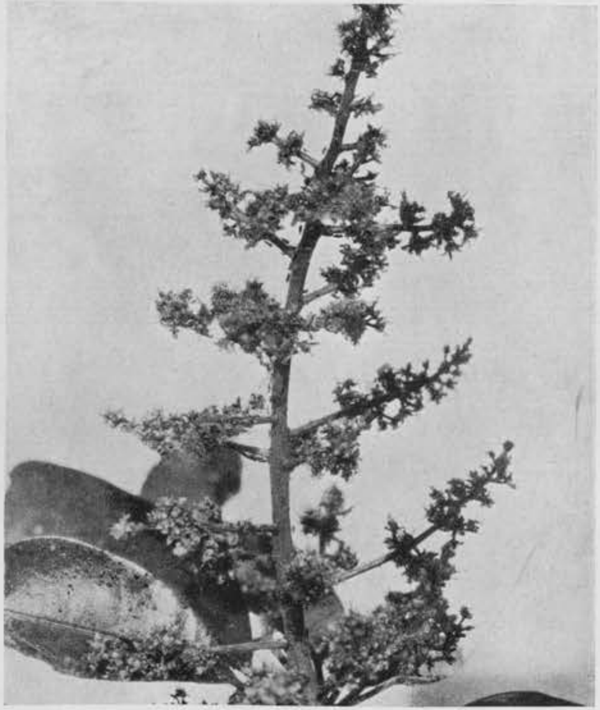

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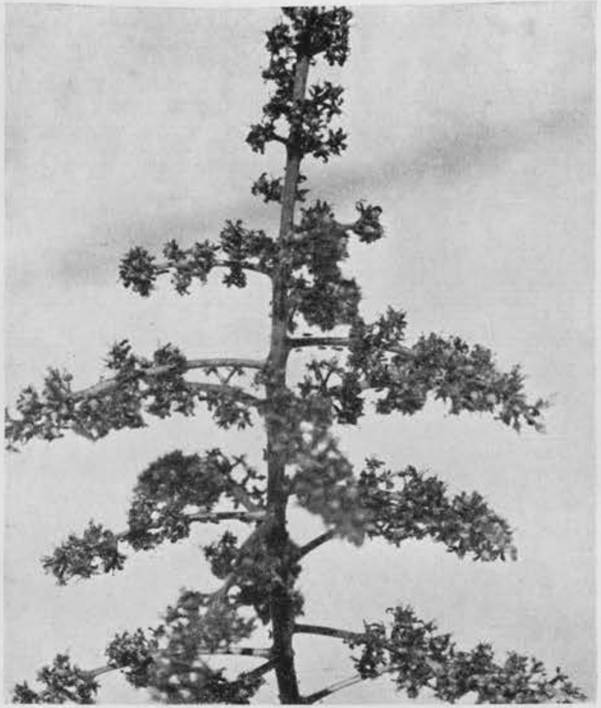

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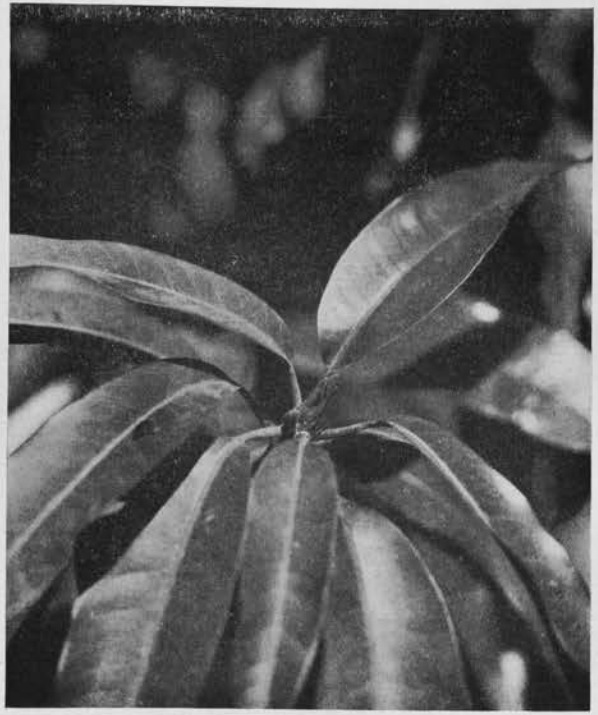

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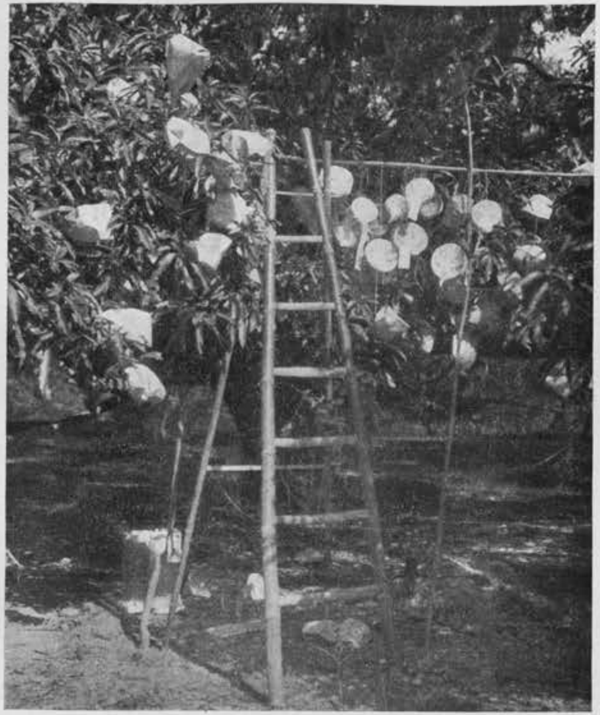

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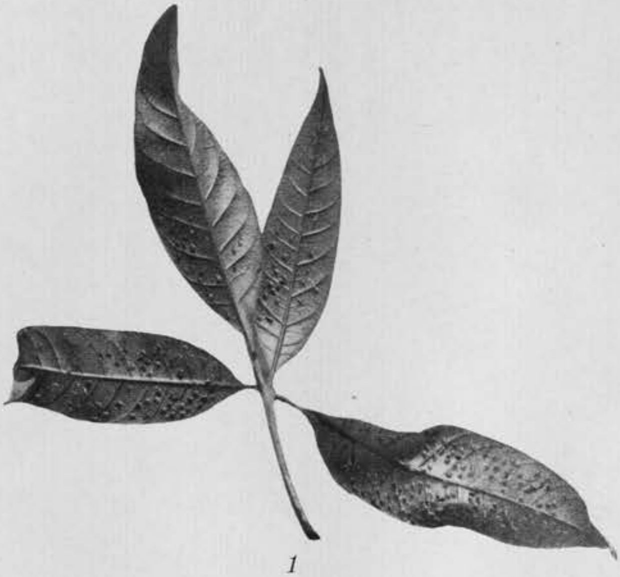

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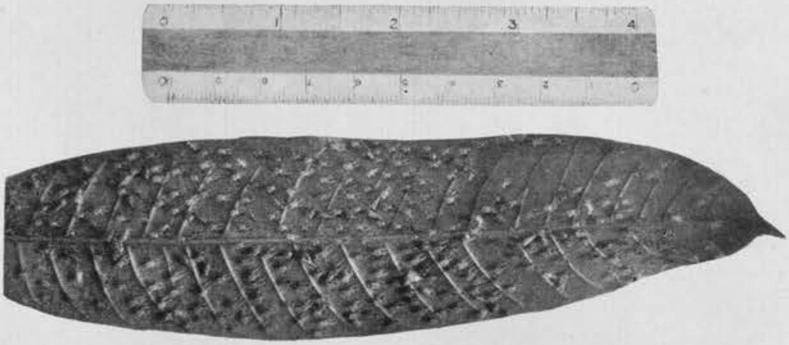

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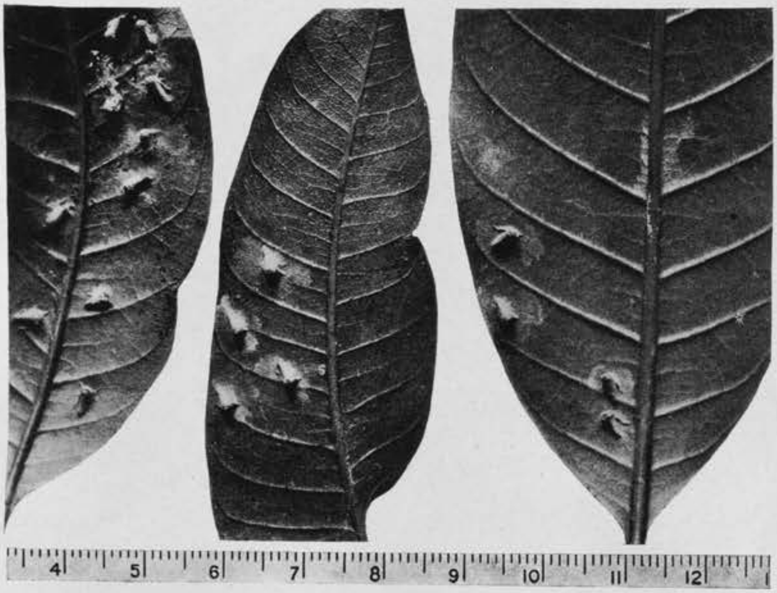

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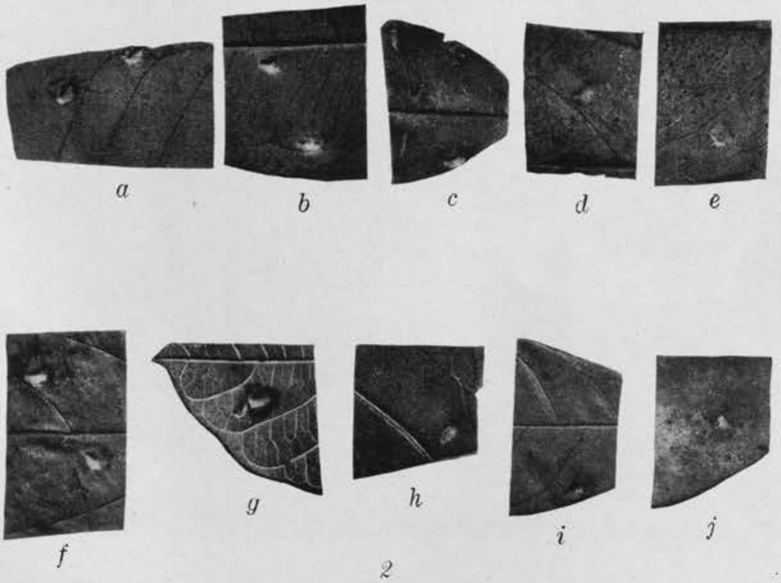

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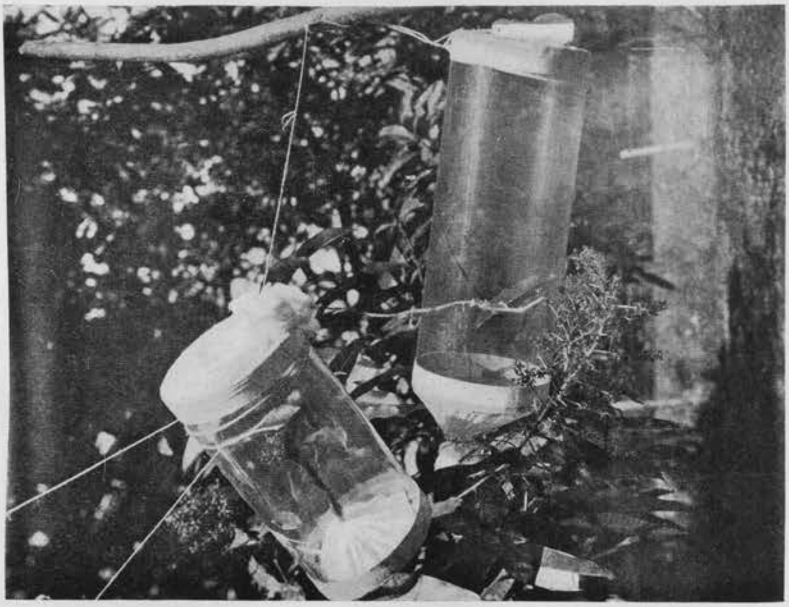

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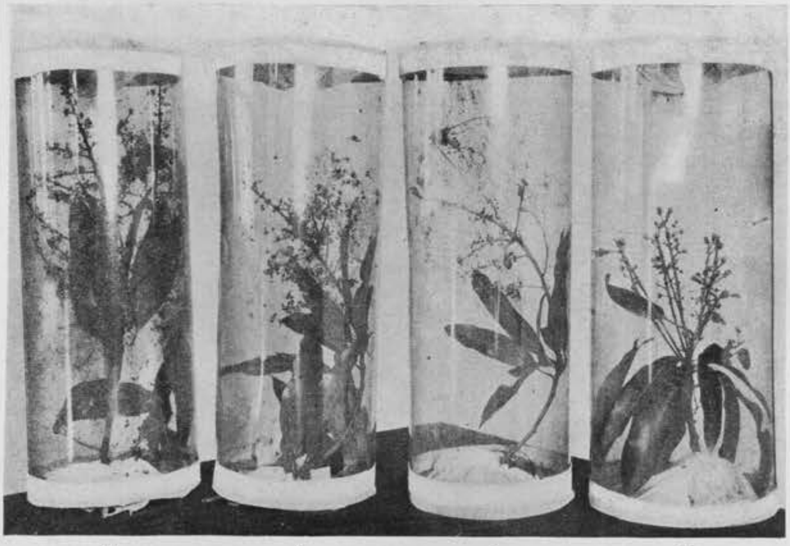

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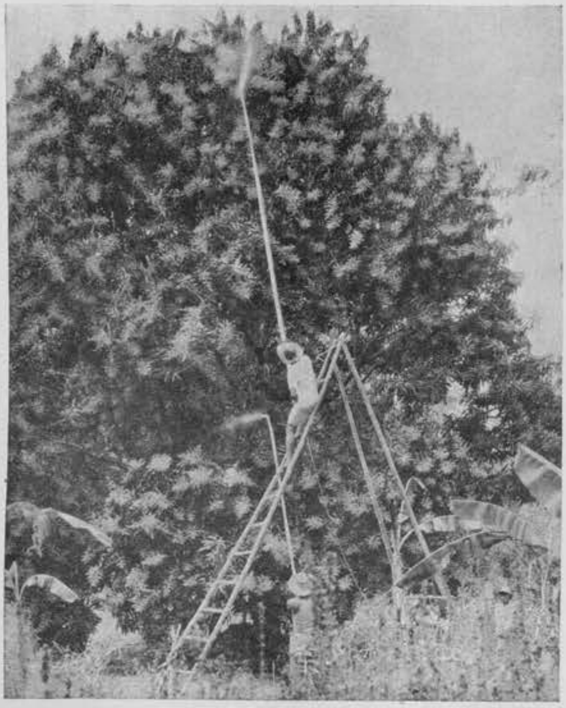

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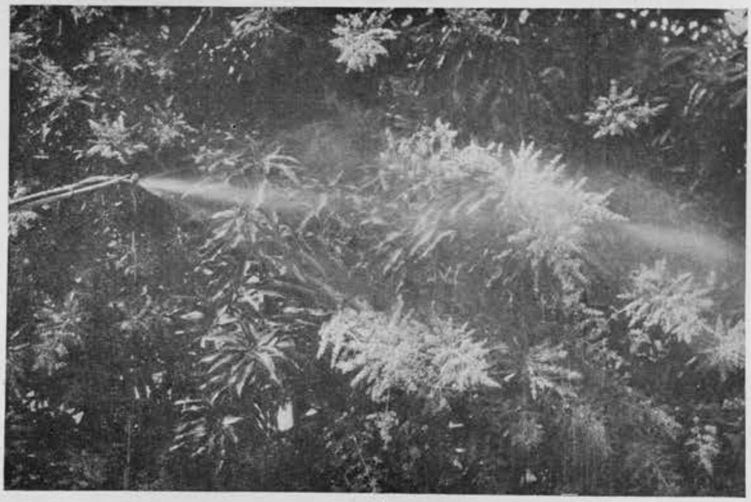

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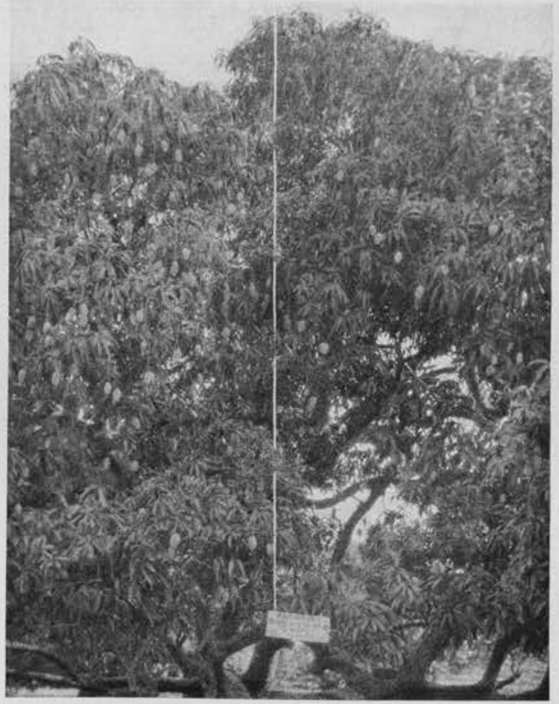

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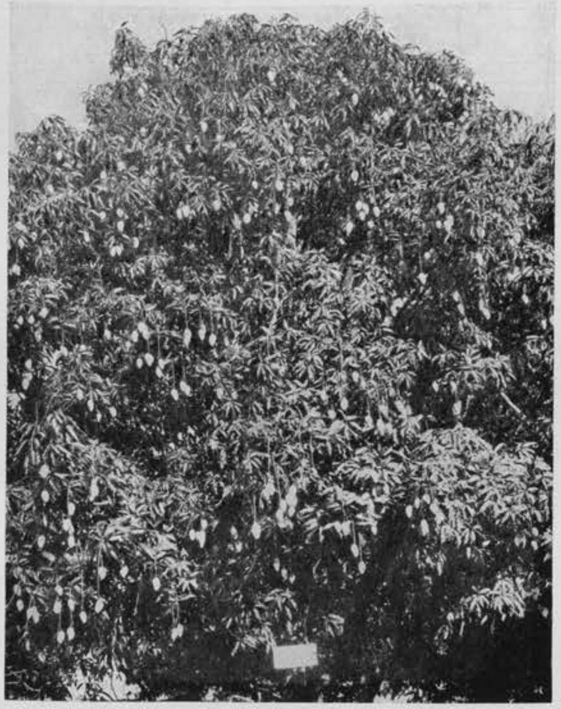

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PLATE 11.

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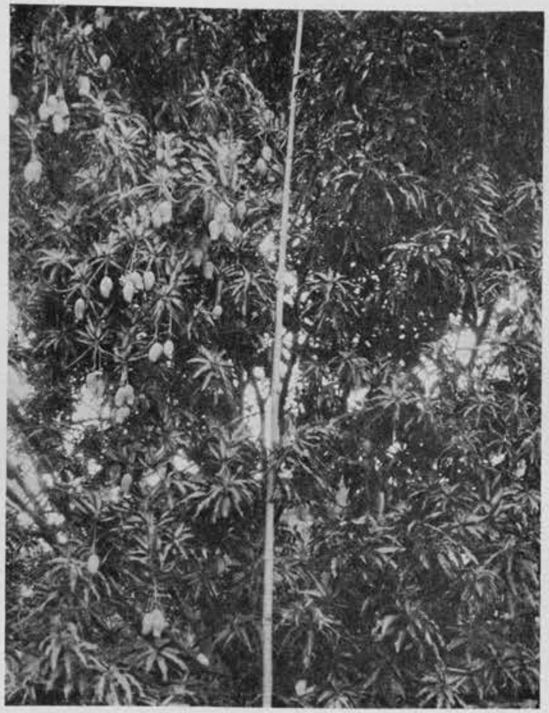
PLATE 12.



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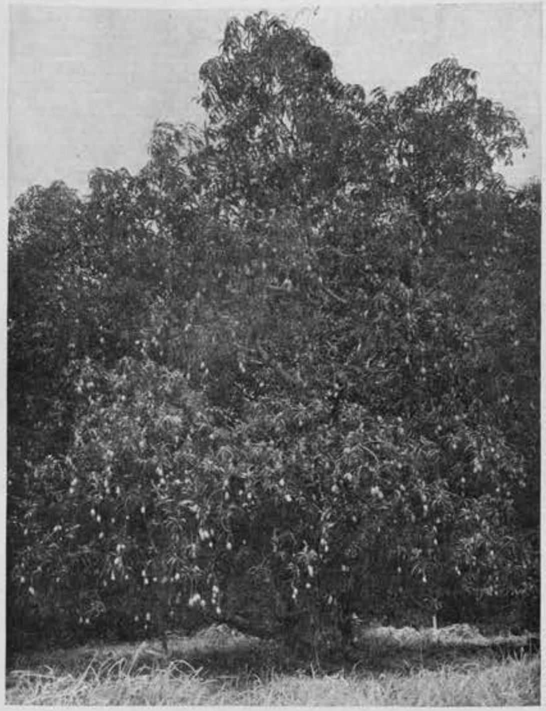

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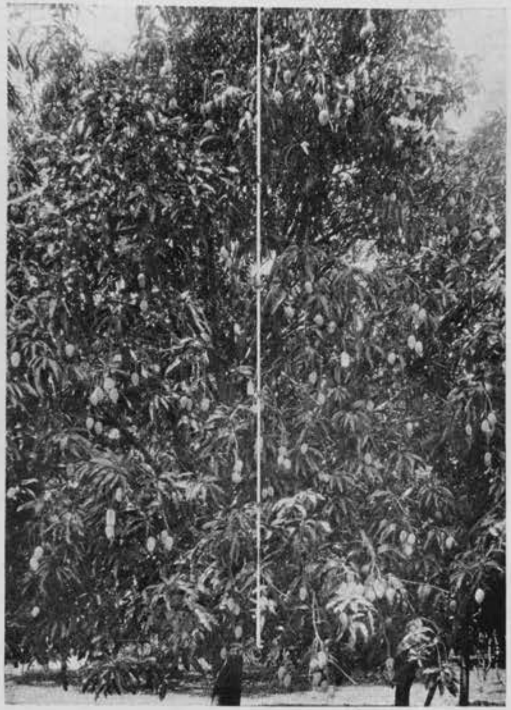

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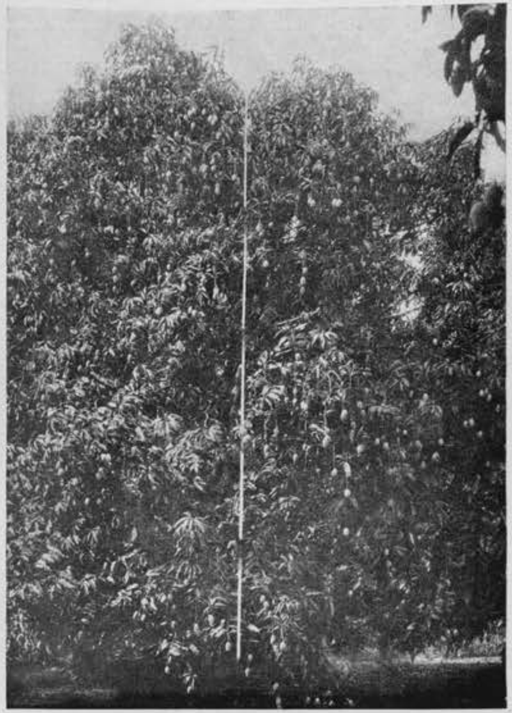

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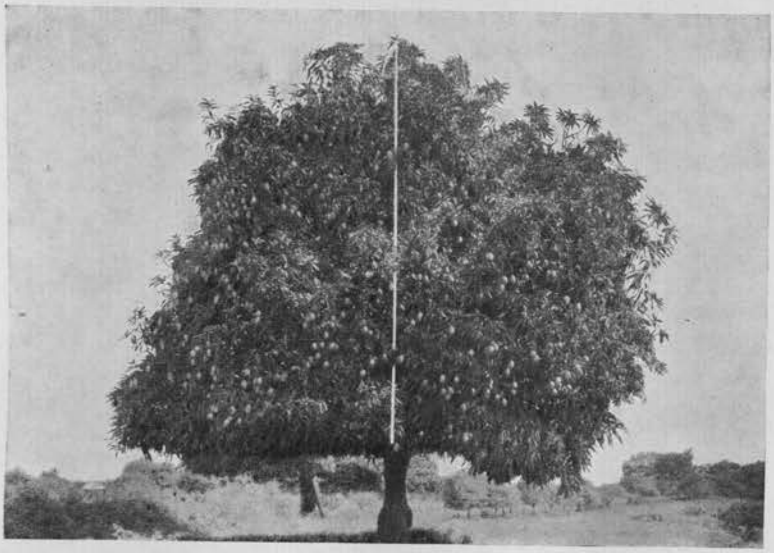

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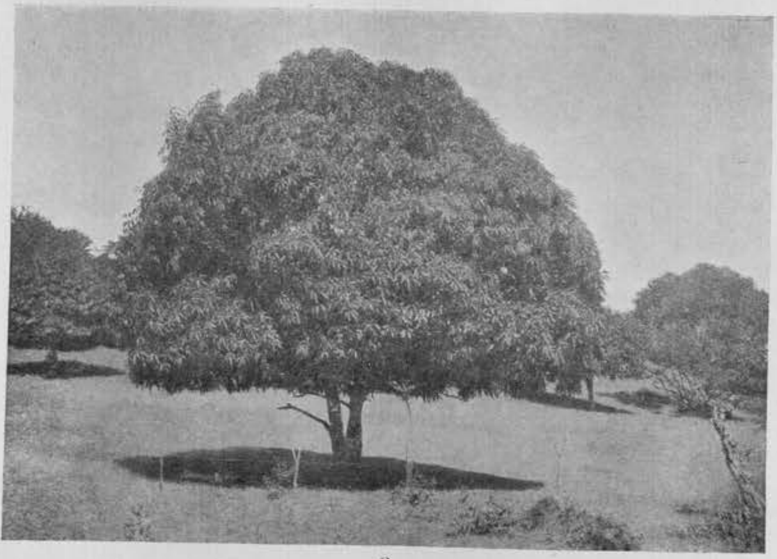

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PLATE 15.

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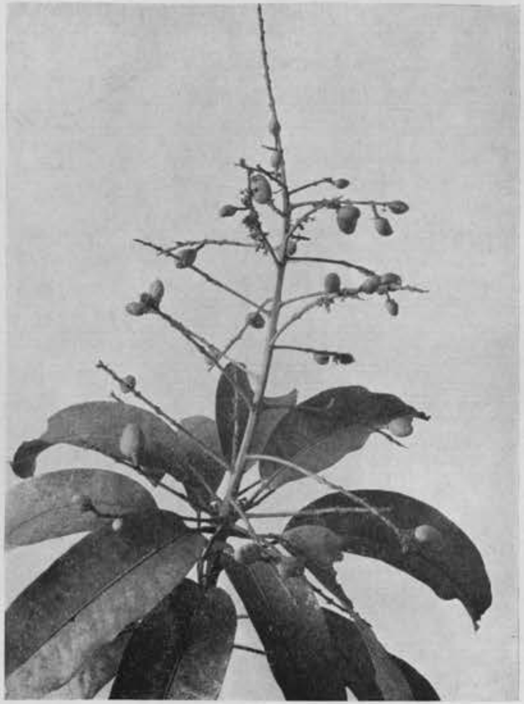
PLATE 16.



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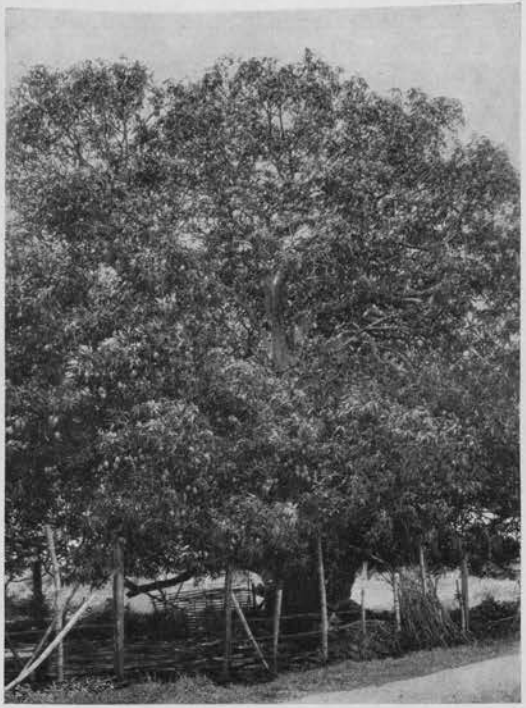

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PLATE 17.

SOLAR ULTRAVIOLET RADIOMETRY *

II, INSTRUMENTS AND METHODS

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Major, Medical Corps, United States Army
Member, United States Army Medical Department
Research Board, Bureau of Science, Manila

ONE PLATE AND FIVE TEXT FIGURES

The problem with which these reports deal is the determination of the energy present in the ultraviolet region of sunlight. An attempt has been made to determine this energy in terms of absolute units—watts per square millimeter—for several contiguous spectral regions in the ultraviolet and short-wave-length visible light of sunlight.

The question of the effect of sunlight on man is one demanding much attention of late. Not the least important phase of this question—and certainly not the least vexing—is the matter of the effect of tropical sunlight on the white race. The military bearing of this question on such problems as the length of the tour of duty in the tropical stations of the Army and Navy is obvious. Heretofore the evidence examined as bearing on this matter has been very largely subjective in nature. The present investigation is an attempt to obtain strictly objective evidence.

In this attempt to obtain objective evidence expressed in physical units, one goal sought was the ability to compare such figures with those now being obtained in other parts of the world. This has not been the case with the majority of the work done in the past on sunlight, using biological or photochemical methods. This aspect will be discussed in more detail later.

More specifically, the goal sought is the determination of the energy in four spectral bands of sunlight; namely, 290 to 310 millimicrons, 310 to 370 millimicrons, 370 to 400 millimicrons, 400 to 460 millimicrons, and the total energy in the sunlight be-

* Submitted for publication July 25, 1932.

tween the limits of 290 millimicrons in the ultraviolet and 1,400 millimicrons in the infrared. This limit in the infrared rather than the extreme solar limit was made necessary by certain transmission characteristics of the filter used. These results have been obtained in two forms; namely, in terms of the percentage of the total solar energy present between 290 and 1,400 millimicrons and in terms of microwatts per square millimeter of surface normal to the incident solar light.

METHODS USED

In the past, two methods of estimating the solar energy have been largely used by biological workers; namely, the effect of the light on animals and photochemical reactions.

Methods using animals have never been quantitatively calibrated in even approximate energy terms. Hence it is impossible to make more than the roughest and most general comparison between the results of any two workers, situated in different regions and using different animals. Even if the same species of animal were used, strain and breed variations are so great as to render quantitative comparison of data impossible.

Various photochemical reactions have been used, such as the decomposition of oxalic acid in a solution of uranyl sulphate, (1, 2, 5, 6) the change of lithopone (zinc sulphide), (3) and the fading of an acetone-methylene blue solution. (4) None of these has been more than very roughly standardized in terms of energy units. Unless all conditions can be exactly duplicated, the reporting of radiant energy in terms of milligrams of oxalic acid decomposed does not convey a great deal of information to the physicist even for purposes of comparison. Two further disadvantages would appear to lie in the selectivity of the reactions with respect to wave length and in the possibility of a considerable temperature coefficient.

The temperature coefficient of the oxalic acid-uranyl sulphate reaction is stated to be 1.035 per 10° by Anderson and Robinson. (2) The temperature coefficient of the fading of the methylene blue-acetone solution appears to be too great to neglect. (4)

The selectivity of these photochemical reactions is far from being all that could be desired. The fading of the methylene blue-acetone solution is effected to a perceptible degree by visible light. The spectral selectivity of the lithopone reaction is narrower—240 to 360 millimicrons—with a maximum at 310 millimicrons. The oxalic acid-uranyl sulphate reaction seems to be activated in some degree by all wave lengths of ultraviolet.(2) If used as a measure of the total ultraviolet energy to which the particular reaction is sensitive, this selectivity is, of course, an advantage, but too often the total reaction has been used as a measure of a narrower band of energy. The photochemical reactions present the advantage of being integrating in effect, hence can be used to express the summation of energy over a given time and offer the further advantage of requiring a minimum of apparatus and attention.

Photographic methods were not considered suitable to the present problem due to difficulties in calibration of the reaction in energy terms.

The photoelectric cell presents much the same situation as regards selectivity to wave length as the photochemical reactions. The range and peak of this selectivity varies with the metal used in the cell. The calibration of the photoelectric cell in terms of energy units is not entirely satisfactory, the cell showing fatigue with age and requiring frequent recalibration.

Many of the circuits for the use of the photoelectric cell depend upon the rate of charge or discharge of a condenser.(9) The very high humidity of the Tropics would in all probability seriously affect such circuits by causing uncontrollable leakage across the condenser terminals and elsewhere. The chances of this occurring will be readily accepted by those who have heard a respectable States's radio degenerate into a spitting, howling instrument of auditory fiendishness after a short exposure to Manila's climate.

In contrast with these selective detectors of radiation the thermopile and bolometer are practically nonselective over the entire wave-length range from the extreme ultraviolet to the very long infrared. Both depend on the heating of a nonselective black surface by the radiation, this heating being measured in the case of the thermopile by the thermoelectric effect, in the case of the bolometer by the change in resistance of the metal heated. In simplicity and ease of manipulation, the thermopile offers many advantages over the bolometer.

The calibration of the thermopile in energy units is fairly simple and stable. For these reasons the thermopile was chosen as the basis of the present work.

GENERAL DESCRIPTION OF METHOD

The most obvious manner in which to employ the thermopile to measure the radiant energy in any spectral region is to expose the thermopile to this radiation and note the deflection of the galvanometer connected to the thermopile. An appropriate filter is then placed over the thermopile and the galvanometer deflection again noted. The difference in the two deflections is, of course, a measure of the energy stopped by the filter. This method necessitates, however, two separate operations between which the intensity of solar radiation may change. Since, as will be shown later, the filter factor of the filter used must be obtained, four separate exposures would be needed. If, however, two thermopiles are connected to a galvanometer, opposing each other, and adjusted to give equal E. M. F. for equal incident radiation, the galvanometer will show no deflection until one of these two thermopiles is covered by a filter, and the deflection then obtained will be a measure of the radiation cut off by the filter. Furthermore, this measure of radiation will be obtained by a single exposure, or if the filter factor must be obtained, the complete measure can be had in two operations rather than four.

In an extension of this principle, Stockbarger(7) has designed a potentiometer circuit in which the galvanometer is used as a null or balance indicator and the percentage of energy passed (or cut off) by the filter is read directly off the potentiometer scale. This is in principle the method used in this work. Two nonselective thermopiles were connected in opposition to a galvanometer through a potentiometer. Four different filters were interposed in turn over one of the thermopiles and the percentage of the solar energy cut off by each filter read off the potentiometer. Finally one thermopile was connected directly to the galvanometer and the deflection produced by total radiation read. The thermopile galvanometer circuit having been previously calibrated in terms of energy units (microwatts per square millimeter), the total energy of the solar radiation could be calculated. By the term "total solar energy" is meant, in this report, the energy passed by a 10-mm stratum of water, including wave lengths 290 to 1,400 millimicrons. The use of this water filter is necessary due to the irregular long-wave cut offs of the glass filters used. The water filter cuts off quite sharply at 1,400 millimicrons.

DETAILS OF INSTRUMENTS

THERMOPILES

The thermopiles were of the general plan of construction of those made by Coblentz.(8) Constantan-copper couples were used, formed from No. 36 Ideal and No. 40 copper wire. A 7-mm length of Ideal wire was cut and the copper wire was soft soldered to each end of this. Targets of silver foil, 0.025 mm thick and 2.5 mm square, were soldered to the junction at the same time, care being taken to secure a butt-to-butt joint of the wires, to have this joint at the center of the target, and to use a minimal amount of solder. It was found less trouble to join the wires and target at the same operation rather than first to join the wires and then attach the targets as has been done heretofore, and it is thought less solder is used. After thorough cleaning from flux the targets and wires were painted with very thin bakelite varnish instead of shellac. The couples were then assembled on a bakelite frame, being held in place with de Khotinsky cement and connected in series with soft solder. The front surface of the "hot" tagets and both surfaces of the "cold" targets were then painted with the usual suspension of lampblack in shellac and the front surface of both "hot" and "cold targets smoked. The completed thermopiles were mounted in a cylindrical case of bakelite, 6 cm in diameter and 9 cm deep, with the target surface 1.5 cm above the bottom of the case. Two slits cut from aluminum were mounted above the targets, the first 1.5 cm above the target, the second 1.5 cm above the first. Each slit was cut to give a 1-mm clearance on all sides of the target surface and was made with beveled edges. The angle subtended on the target by the upper split was about 8 degrees. The case was closed with a bakelite cover which mounted a crystal-quartz window, made of a plano-convex spectacle lens of about 2 diopters focus.

This case was then placed in a similar larger bakelite case with a clearance on sides and bottom of about 6 mm. The cover of the inner case fitted snugly into the outer case, giving an air space of about 6 mm on the bottom and sides of the inner case.

As finally constructed one thermopile (TP_1) consisted of 13 double junctions with a total net target surface of 2.5 × 29 mm = 72.5 sq. mm. The other (TP_2) consisted of 11 double junctions with a total net target surface of 2.5 × 24 mm = 60 sq.

mm. The resistance of TP_1 (13 targets) was 4.8 ohms, of TP_2 (11 targets), 3.6 ohms.

The two thermopiles, each in its double-wall case, were then mounted side by side in a wooden box, large enough to provide at least a 1-inch air space on all sides of each case. The top of this case was provided with means to carry a quartz water cell immediately above each thermopile, and above these water cells trays were fitted to hold either a single or double filter above each thermopile. The box was finally provided with a double-walled top of sheet aluminum. In this there were two rectangular holes with beveled edges, properly spaced to fall over each thermopile, and a shutter was constructed whereby both holes could be closed or opened simultaneously. The box was provided with a second bottom hinged along one side to the box. This bottom had a screw socket for attachment to a heavy tripod. By this means the box could be inclined and rotated so as to allow direct sunlight to fall upon the thermopile targets. The inclination was maintained by two pivoted arms fixed by thumb screws. Along one corner of the box was fastened a small brass tube bearing at the lower end a small piece of brass soldered at an angle of 45° to the axis of the tube. The upper end had two crosswires inserted. When the tube was pointed at the sun the shadow of these crosswires fell on the small reflector at the other end, which was painted white with a small black spot in the center. The tube was so attached to the box that when the sun fell directly on the thermopile targets the crosswire shadow fell on this black spot. Thus, the orientation of the thermopiles on the sun was maintained.

RADIATION POTENTIOMETER

The basic circuit for the radiation potentiometer is shown in fig. 1. This is the figure given by Stockbarger in the article already cited.(7) T_1 and T_2 are the two thermopiles, R_1 is the resistance used to adjust the E. M. F. of T_1 when both thermopiles are exposed to equal radiation so that there is no deflection in the galvanometer, G. For this condition the sliding contact S is at the extreme right end of R_2 and R_3, the two slide-wire resistances.

If a filter is placed over T_2 the E. M. F. of this thermopile will be lowered in proportion to the amount of radiation stopped by the filter, the balance of the two E. M. F.'s will be disturbed and the galvanometer show a deflection. If now S be moved

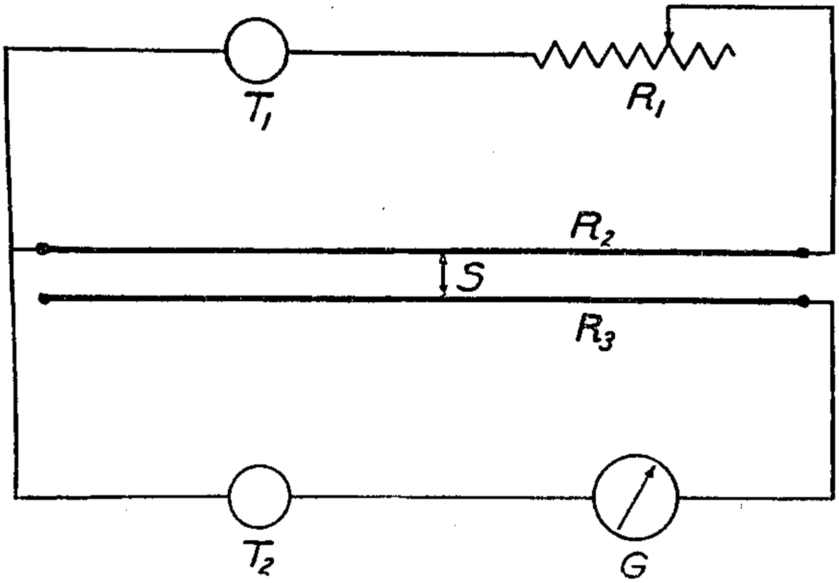


FIG. 1. Basic circuit of radiation potentiometer. (From Stockbarger.)

to the left, the E. M. F. applied from T_1 to the galvanometer will be decreased and a balance again be obtained. If R_2 be graduated in 100 parts the position of S will at once give the percentage of the E. M. F. of T_1 necessary to balance the E. M. F. of T_2 with the filter, which will be equal to the percentage of radiation passed by the filter on T_2.

R_3 enables the damping resistance of the galvanometer circuit to be kept constant whatever the position of S.

The circuit actually used for the potentiometer is shown in fig. 2. In order to keep the instrument in a portable form, the slide wires R_2 and R_3 of fig. 1 were divided into ten sections each, one section of each being formed as the slide wire with movable contact, the other nine sections of each wire being formed by the tapped resistance coils and switches shown. The right-hand resistance coil serves as the nine-tenths of R_3, while the other two coils serve similarly for R_2. The only other important modification of the original circuit is the switch in the negative thermopile leads. This serves to cut out TP_1 and connect TP_2 direct to the galvanometer (all resistance switches being on point 9 and slider on 10) with only the one-tenth section of R_3 in the circuit. Calibration of thermopile TP_2 and the galvanometer was made with this circuit included. The shunt shown

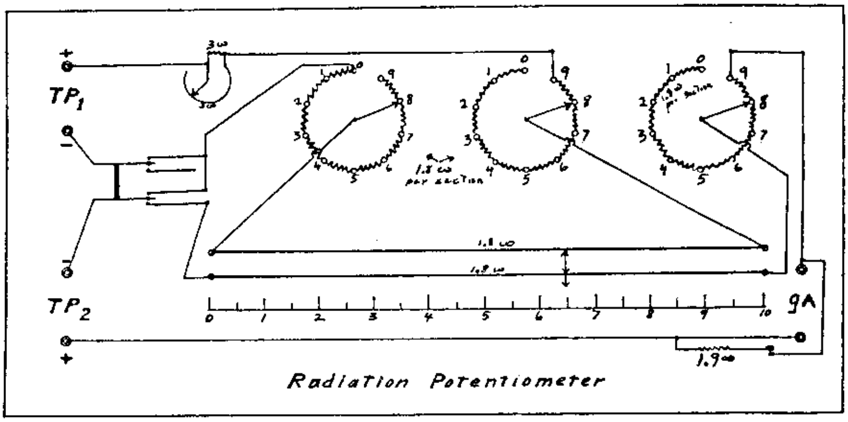


FIG. 2. Radiation potentiometer circuit as used.

across the galvanometer terminals was included to permit a more sensitive galvanometer to be used if necessary, but so far has not been used.

Plate 1 shows the instrument as constructed. It would, of course, be possible to include all three resistance coils under one three-bladed switch, making the instrument somewhat more convenient to use and less liable to error in setting all three switches on the same point. However, such a three-bladed switch was not available in Manila. The resistance coils and slide wires were made of manganin wire, contact points and binding posts of very heavy brass. The three tap switches were of low-resistance contact type from Army Signal Corps radio instruments. The slider was of clock spring. The cut-out switch was of standard telephone type. The instrument was constructed on a 1-inch bakelite panel and housed in a heavy oak box with a large closed air space beneath the panel. The heaviness of construction and the evenness of temperature from hour to hour in the Philippines may account in part for the steadiness of operation of the instrument. At all events very little trouble such as zero shift has been experienced.

GALVANOMETER

The galvanometer used was a suspended-coil portable type made by Leeds and Northrop. The coil and suspension had an overall resistance of 22 ohms. With the reading telescope provided, the sensitivity was 2.7 divisions per microvolt.

While the resistance of the thermopile-potentiometer-galvanometer circuit was not exactly that of the critical damping resistance, the damping was such that satisfactory deflection of the galvanometer was attained in a reasonably short time. Connections from thermopiles to the potentiometer were made of a 45-foot four-conductor cable made of two lengths of double twisted, No. 18 lamp cord tied into a cable with cotton bandage. Connection from potentiometer to galvanometer was made by a 3-foot length of double lamp cord. All connection ends were made of large-size brass spade tips.

If the potentiometer were adjusted for balance and the thermopiles were of the same heat capacity, no deflection of the galvanometer should occur on opening or closing the shutter in front of the thermopiles. However, as made, thermopile TP_1 apparently had a slightly smaller heat capacity than TP_2. This caused a small deflection of the galvanometer to one side when the shutter was opened and another deflection to the opposite side when the shutter was closed. These two deflections returned to the zero position very quickly. The time required for the thermopiles to attain thermal equilibrium appeared to be about the same as the period of the galvanometer coil. Since no assurance could be had of a better match in thermal capacity between other thermopiles that might be made, no attempt was made to improve upon the match of TP_1 and TP_2, since this inequality caused but little delay.

FILTERS

As has been stated, a water cell was used over each thermopile, to secure a uniform long-wave cut off at about 1,400 millimicrons for all filters. These water cells were of fused quartz, 6.5 cm in diameter and 10 mm in internal depth. They were filled with freshly distilled water, hot from the still. This water was changed weekly.

The filters used to cut off the various spectral bands were as follows with the respective wave lengths of zero transmission:

Filter No.	Glass.	Thickness.	Cut off.
		mm.	*Millimicrons.*
30	Window	2.26	310
29	Noviol O	2.54	370
28	Noviol A	2.53	400
27	Noviol C	3.00	460

Three each of these four filters were used. The transmission curves of these filters were determined photographically by a small Hilger quartz spectrograph by determining the wave length at which the density of the area of the negative made with filter matched the area made without the filter, the exposure through the filter being a known multiple of the exposure without the filter.

When thermopile TP_2 was connected directly to the galvanometer and direct sunlight admitted to the thermopile, the galvanometer deflection was many times full scale. To keep the deflection on the scale, wire screens of copper gauze were used. These were constructed of copper gauze of 100- and 200-mesh soldered to heavy copper frames. The transmission of the screens was determined by means of a standard carbon-filament lamp, thermopile, and galvanometer. The construction and transmission of the four screens used was as follows:

Screen No.	Mesh.	Layers.	Transmission.
22	200	Single	0.215
23	200	Two	0.035
24	100	Single	0.332
25	100	Two	0.109

For ordinary, bright sunlight, screen No. 23 with a transmission of 3.5 per cent kept the galvanometer deflection about one-half to two-thirds full scale.

The so-called "filter factor" of a transmission filter has been defined (10, 11) as the ratio of the energy transmitted by a single filter to the energy transmitted by two superimposed identical filters. The first of these two filters isolates the spectral band to be transmitted by the second filter, and the transmission of this band by the single filter is then measured. The approximate transmission of the filter will then be given by the quotient of the transmission of the single filter divided by this filter factor. The value of the filter factor evidently depends on the spectral energy distribution of the light and since this is the unknown being measured, and presumably varies, the filter factors of each filter must be determined as a preliminary to each analysis. As was stated earlier (first paragraph of description of method), this would necessitate four, or at least three, separate readings being taken of galvanometer deflection, were that method used. With the radiation potentiometer two readings suffice. In the first a single filter is placed over TP_1 and two filters identical with the first are placed over TP_2, the thermopiles pointed at the light and the potentiometer adjusted to give zero deflection. The reading of the potentiometer then gives the filter factor directly, since its reading is the ratio above mentioned. The filter over TP_1 and one of the filters over TP_2 are then removed and the potentiometer again adjusted to zero deflection.

This second reading of the potentiometer divided by the first reading (filter factor) gives the percentage of energy transmitted by the filter. The determination of the wave-length boundaries of this transmitted energy will be discussed later.

CALIBRATION IN ENERGY UNITS

The calibration of thermopile TP_2 and galvanometer in energy units was made by comparison at a distance of 2 meters with two standard carbon filament lamps obtained from the Bureau of Standards through the courtesy of Dr. W. W. Coblentz. The calibration was made with the potentiometer and connecting leads in circuit. The thermopile had the quartz window in place, but the water cell was not used. The filter factor of the water cell was then determined on several different cloudless days when the sun appeared of constant intensity. The calibration values of the thermopile were divided by this filter factor. Values are given in terms of microwatts per square millimeter. For the circuit consisting of TP_2, galvanometer IC_3, the radiation potentiometer and the 45-foot lead, with no water cell, the calibration value was taken as 1.31 microwatts per square millimeter per centimeter deflection. The filter factor of the water cell was taken as 0.843. Hence, the overall calibration was $\frac{1.31}{0.843} = 1.55$ microwatts per square mm per cm deflection, or

$$\frac{\frac{1.55 \text{ watts} \times 10^{-6}}{\text{mm}^2}}{\text{cm}}.$$

With any but the dullest sun the screens already mentioned were used and the above value divided by the transmission of the screen used. Hence, for the combination most used (screen 23 and the circuit just mentioned) the overall factor would be

$$\frac{\frac{1.31 \frac{\text{microwatts}}{\text{mm}^2}}{\text{cm}}}{0.843 \times 0.035} = 44.3 \frac{\frac{\text{microwatts}}{\text{mm}^2}}{\text{cm}}.$$

CALCULATION AND REDUCTION OF DATA

AIR MASS

Air mass was taken as the secant of the zenith angle of the sun, this zenith angle being calculated from the known latitude of the place and the time of observation. This calculation might be made by the fundamental formula

$$\sin h = \sin L \sin d + \cos L \cos d \cos t, \text{ in which}$$

h = sun altitude
L = latitude of place
d = declination of sun
t = time of observation,

but is more conveniently made by the haversine modification

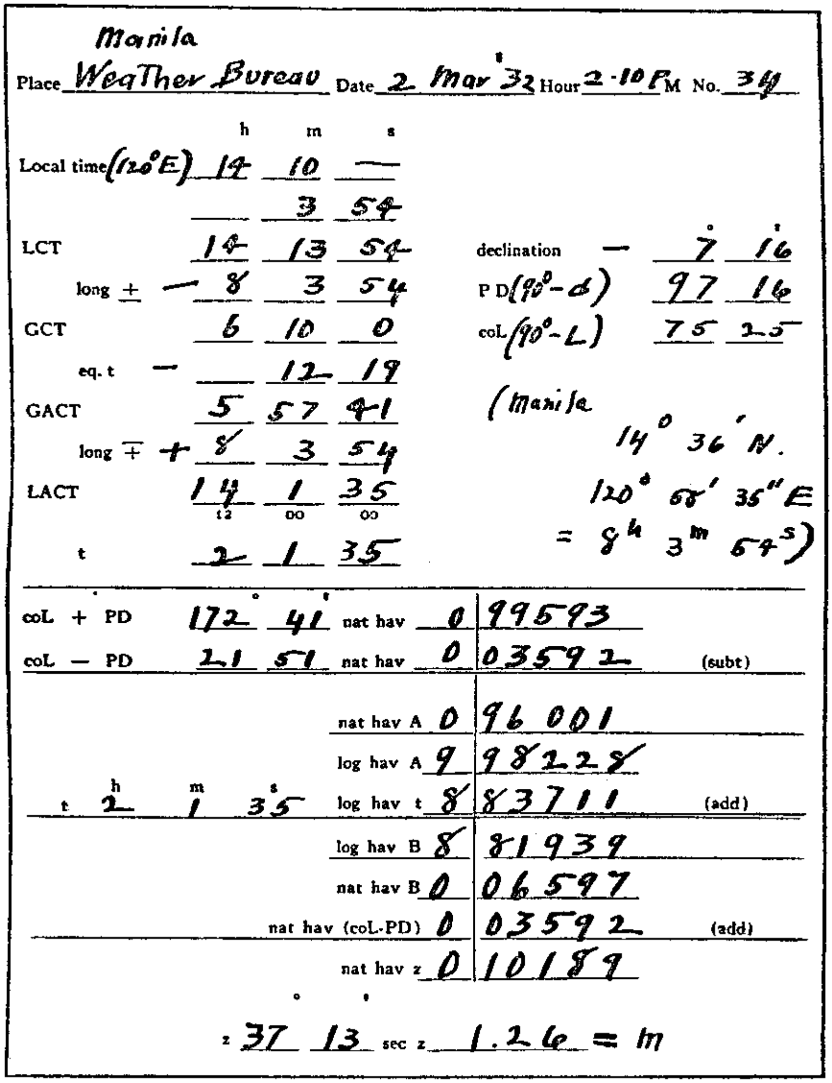
$$\text{hav } z = \text{hav } (\text{Co. } L - PD) + [\text{hav } (\text{Co. } L + PD) - \text{hav } (\text{Co. } L - PD)] \text{ hav } t, \text{ in which}$$

z = zenith angle
Co. L = colatitude
= 90° — latitude
PD = polar distance
= 90° — declination
t = time.

For the working of this the haversine tables contained in Bowditch's American Practical Navigator(12) and the calculation form shown in fig. 3, which is adopted from Bowditch, will be found convenient.

REDUCTION FACTORS

The greatest difficulty in measurement of radiation by a filter method is due to the fact that no filter we possess has a rectangular cut off. If this could be obtained; that is, if the filter transmitted radiation equally to a certain wave length and the transmission dropped to zero abruptly at this point, the difference in instrument readings with and without the filter would indicate the radiation cut off. But all actual filters have a cut off with a decided slope and this slope is usually sigmoid. In this case, an appreciable amount of energy is cut off by the filter at wave lengths longer than that of zero transmission, and the energy stopped by the filter as represented by the difference in instrument readings includes not only the portion desired but also energy beyond. To cite a specific instance: For filter No. 30 of window glass with zero transmission at 310



Manila
Place Weather Bureau Date 2 Mar '32 Hour 2·10 PM No. 34

		h	m	s			°	′
Local time (120°E)		14	10	—				
			3	54				
LCT		14	13	54	declination	—	7	16
long ±	—	8	3	54	P D (90°−δ)		97	16
GCT		6	10	0	coL (90°−L)		75	25
eq. t	—		12	19	(Manila			
GACT		5	57	41				
long ∓	+	8	3	54	14° 36′ N.			
LACT		14 12	1 00	35 00	120° 68′ 35″E			
t		2	1	35	= 8ʰ 3ᵐ 64ˢ)			

	°	′				
coL + PD	172	41	nat hav	0	99593	
coL − PD	21	51	nat hav	0	03592	(subt)

			nat hav A	0	96001	
			log hav A	9	98228	
t 2 h	1 m	35 s	log hav t	8	83711	(add)
			log hav B	8	81939	
			nat hav B	0	06597	
			nat hav (coL-PD)	0	03592	(add)
			nat hav z	0	10189	

z 37° 13′ sec z 1.26 = m

FIG. 3. Form for calculation of air mass.

millimicrons, the spectral region for which this filter was used was 290 to 310 millimicrons. Say the transmission, as obtained by the potentiometer and corrected by the filter factor, was 0.98. The difference of 0.02 between 0.98 and 1.00 is of course the total energy cut off by the filter, but this represents a great deal more than the energy actually present in sunlight between 290 to 310 millimicrons, since to the energy in this band is added that cut off by the filter in the region of the sloping part of its transmission curve up to λ 535 millimicrons. Therefore, factors must be found by which this total excluded energy may be reduced to give the fractional amount actually in the band desired.

The calculation of this reduction factor was made as suggested by Stockbarger, Dingee, and Burns(13) and by Coblentz and Stair.(14, 15) Referring to fig. 4, curve A is the solar spectral energy distribution curve for air mass 0.0, that is, above the atmosphere, compiled from data of the Smithsonian Institution(16) and of Forsyth and Christison.(17) Curve B is curve A multiplied by the transmissions of air for air mass 1.00. These transmission factors were compiled from data of the Smithsonian Institution(18) and Forsyth and Christison.(17) For air mass other than 1.00 the transmission was taken as $T_m = T_o{}^m$ where T_o = transmission for air mass 1.00, m = air mass. Curve C is curve B multiplied by the maximum transmission of the filter. Curve D is curve B multiplied by the transmission factors of the filter for each wave length. The shaded area between curves C and D then represents the total energy cut off from sunlight by the filter. The ratio of the area included between λ 290 millimicrons and λ 310 millimicrons to this total area is the reduction factor sought, being the fraction of the total excluded energy, which is contained in the desired spectral band λ 290 to 310 millimicrons.

The areas were computed by counting small squares on a large-scale graph. This computation was repeated for various air masses and the factors so obtained used to construct a graph, fig. 5. From this graph the reduction factor for any required air mass up to 5.0 may be read. For stations other than at sea level the air mass was reduced to sea-level values by

$$M_{sl} = M \frac{B}{760},$$

B being obtained from the elevation by the equation(19)

$$\text{Elevation in feet} = 52500 \frac{760 - B}{760 + B}.$$

Reduction factors for the other filters used were obtained similarly to give the energy in the desired spectral bands.

PROCEDURE

The procedure of a determination for any one spectral band has been given in the discussion of filter factor above. In

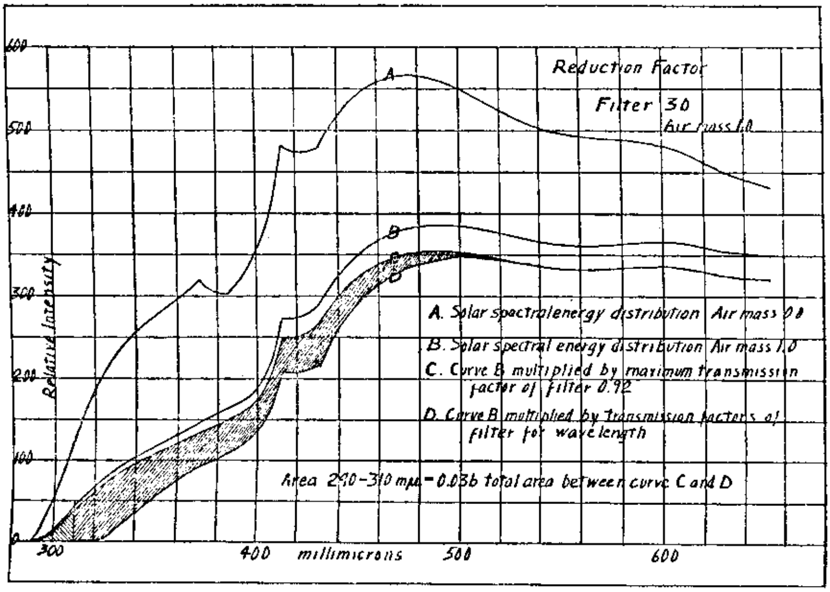


FIG. 4. Graphic calculation of reduction factor for filter 30.

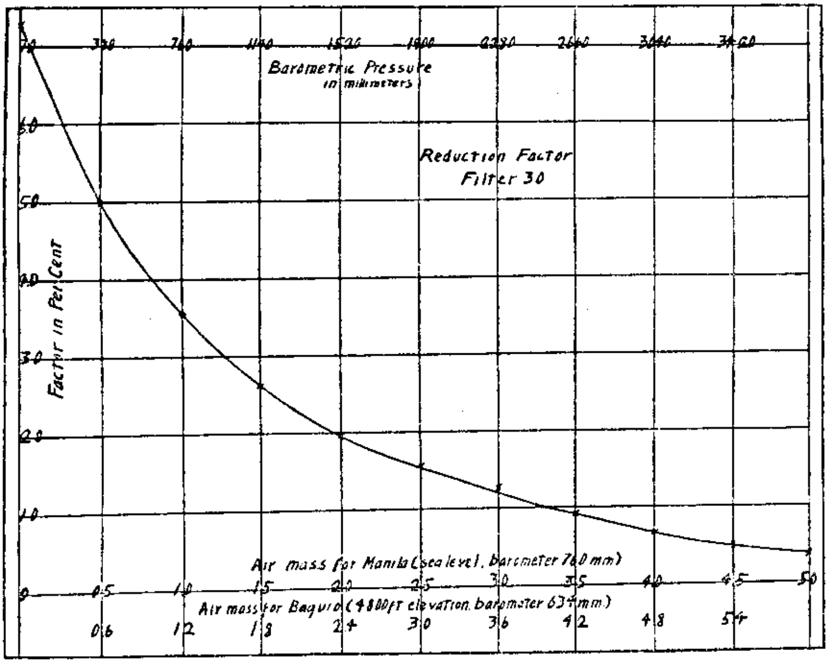


FIG. 5. Reduction factor for filter 30 for varying air mass.

actual use the thermopile box on its tripod was placed to command an unbroken view of the sun. The potentiometer and galvanometer were placed under a shelter affording shade and freedom from air currents across the potentiometer panel or galvanometer. The two stations were connected by the 45-foot connector. The potentiometer and thermopiles were adjusted to balance, and the transmissions of the four filters were determined in succession as rapidly as possible. The switch was then thrown to connect TP_2 direct to the galvanometer and the total energy was determined. The switch was then thrown back for potentiometer connection and the balance without filters tested. If this was not satisfactory the run was rejected. Time of run was taken as being that when the shutter was thrown open for the third filter readings, experience showing this to be the nearest to midpoint of a run. A complete run of the four bands and total energy usually took between seven and ten minutes. With clear sky runs were made every thirty minutes, with cloudy sky runs were made as often as clear sun appeared for a sufficient time. Runs interrupted by clouds were rejected.

The percentage transmission obtained for each of the four filters subtracted from 100 per cent gave the percentage of the solar energy between λ 290 and 1,400 millimicrons cut off by each filter. Each of these percentages was next multiplied by the reduction factor appropriate to the filter and to the air mass at the time. The four products resulting then gave the percentage of total energy lying respectively between

(*a*) 290–310 millimicrons
(*b*) 290–370 millimicrons
(*c*) 290–400 millimicrons
(*d*) 290–460 millimicrons.

The difference between (*a*) and (*b*) is evidently the percentage of energy in the band (*e*) 310 to 370 millimicrons. Similarly, (*c*) minus (*a*) gives the energy between (*f*) 310 to 400 millimicrons, and (*d*) minus (*a*) gives (*g*) 310 to 460 millimicrons. Then, (*f*) minus (*e*) gives (*h*) 370 to 400 millimicrons, and (*g*) minus (*e*) gives (*i*) 370 to 460 millimicrons. Finally, (*h*) minus (*i*) gives (*j*) 400 to 460 millimicrons. The total energy value found multiplied by these resultant percentages gives the energy in each band in microwatts per square millimeter. The following specimen calculation of an actual run illustrates this:

Camp John Hay, Baguio, Mountain Province, P. I., January 5, 1932; time, 11.21; air mass, 1.31; total energy, 922.

EXPERIMENTAL DATA.

Filter.	Transmission.	Per cent Cut off.	Reduction factor.	Corrected Per cent cut off.	Band
30	0.980	0.020	0.034	0.00068	(a)
29	0.948	0.052	0.34	0.018	(b)
28	0.894	0.106	0.47	0.050	(c)
27	0.808	0.192	0.72	0.140	(d)

CALCULATED DATA.

Band.	Per cent.	Microwatts per sq. mm.
Total 290–1,400	100.0	922
(a) 290–310	0.068	0.63
(b) 290–370	1.8	16.6
(c) 290–400	5.0	46.0
(d) 290–460	14.0	129
(e) (*b* minus *a*) 310–370	1.7	16.0
(f) (*c* minus *a*) 310–400	4.9	45.4
(g) (*d* minus *a*) 310–460	13.9	128
(h) (*f* minus *c*) 370–400	3.2	29.4
(i) (*g* minus *e*) 370–460	12.2	112
(j) (*i* minus *h*) 400–460	9.0	83

DISCUSSION

With clear sun the sensitivity of the instruments was sufficient to show a difference of 0.1 division on the potentiometer scale equivalent to 0.1 per cent transmission. As has been said, runs were made only with a clear, uninterrupted sun. The energy values for each individual band were obtained from the percentages of the total energy. Several minutes necessarily elapsed between any one percentage and the total determination. Hence this requirement of an uninterrupted sun was essential.

The angle subtended by the upper thermopile slit on the target has been stated to be about 8 degrees. Taking the semidiameter of the sun as being roughly 16 minutes of arc, illumination from an appreciable area of the sky adjacent to the sun of course reached the target, as well as the direct solar light. With clear sun this indirect sky illumination was regarded as negligible.[1]

With the sun clouded over even lightly this ratio of direct to indirect illumination would vary. This variation was shown by a disturbance in the zero balance of the potentiometer. The actual angle subtended by the slit on the thermopile target differed in the two thermopiles. The facilities available when the thermopiles were made were such that this difference could not be avoided in the "homemade" apparatus. This difference in angle caused a variation in this ratio of direct to indirect light to affect the thermopiles unequally, disturbing the zero balance.

The regularity with which the zero balance of the start of a run was found undisturbed at the end of the run is evidence that determinations with clear sun were not appreciably affected by this angle difference. Slits with closer clearance were tried, but their use necessitated such exact orientation on the sun, if shadows on part of the target were to be avoided, that the time required for a run was lengthened unduly.

Another possible explanation of this difference in zero balance obtained with clear sun and with a clouded sun would of course be that one or both of the two thermopiles was selective in response to radiation. This possibility was tested by exposing the two thermopiles to clear sun with and without identical filters over each thermopile. The zero balance without filters was disturbed but a negligible amount by this procedure using any of the four filters No. 30, 29, 28, and 27 and, in addition, Corex red purple, Corex blue purple, and the purple gelatin component of a Wratten No. 2 safelight. Consequently it is felt that the response of both thermopiles was nonselective and that the assumption was justified that this difference in balance with clear and with overcast sun was due to the difference in the ratio of direct to indirect light on the target.

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[1] Galvanometer deflections were obtained with the thermopile pointed first directly at the sun and second at the sky immediately adjacent to the sun. The mean ratio of these two deflections for a series of eleven determinations was 0.0028, with a maximum ratio of 0.0052 and a minimum ratio of 0.0012. These were obtained on a day when the sky was not entirely clear, the sun being overcast with a marked haze. With a completely clear sun even lower ratios would be expected. The values obtained for direct sun are therefore regarded as containing a component of sky light of not more than 0.005 of the total and for most of the values this component is about 0.002.

The limitation of the method to use with cloudless sun is not regarded as being as objectionable as might first appear. The basic question which this work attempts to answer is the partial spectral composition of sunlight. If this must be limited to sunlight unfiltered by clouds, the results obtained will probably be on a better basis for comparison with results obtained on similar sunlight elsewhere in the world than if the problem were complicated by the intrusion of such factors as comparative cloudiness of different regions. The problem is one of solar radiation and not of sunshine as affected by cloudiness.

ACKNOWLEDGMENT

The sincere thanks of the writer are offered to Colonel Henry H. Rutherford, Medical Corps, United States Army, Colonel Kent Nelson, Medical Corps, United States Army and Major Rufus L. Holt, Medical Corps, United States Army, for their official support and personal encouragement of this work. Sergeant Loyd Stevens, Medical Department, United States Army, rendered valuable assistance in the construction and calibration of the instruments. The writer's thanks are due Dr. W. W. Coblentz, of the United States Bureau of Standards for helpful criticism and for furnishing the standard lamps used for calibration. The aid rendered by the Rev. Miguel Selga, S. J., director of the Philippine Weather Bureau, both by advice and criticism and by permitting the use of the Manila Observatory for observation on Manila sun, is gratefully acknowledged. Private First Class Gervacio R. Sales, Medical Department, United States Army (Philippine Scouts), rendered most valuable assistance in making the actual observations on the sun. The writer is especially indebted to Mr. Roy Thorson, of Clark and Company, Manila, for his great help in grinding and polishing the quartz used in the thermopile.

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ABSTRACT

Instruments and procedures used in quantitative evaluation of four spectral bands of sunlight are described. These four spectral bands were 290 to 310, 310 to 370, 370 to 400, and 400 to 460 millimicrons. Two thermopiles connected in opposition through a potentiometer circuit to a galvanometer were used. Four glass filters served to cut off increasing amounts of light. The graphical calculation of factors for these filters is described by which the energy excluded in the definite spectral bands desired might be computed. Results obtained in the Philippine Islands and elsewhere will be published in subsequent articles.

ILLUSTRATIONS

PLATE 1. Radiation potentiometer.

TEXT FIGURES

FIG. 1. Basic circuit of radiation potentiometer. (From Stockbarger.)
2. Radiation potentiometer circuit as used.
3. Form for calculation of air mass.
4. Graphic calculation of reduction factor for filter 30.
5. Reduction factor for filter 30 for varying air mass.

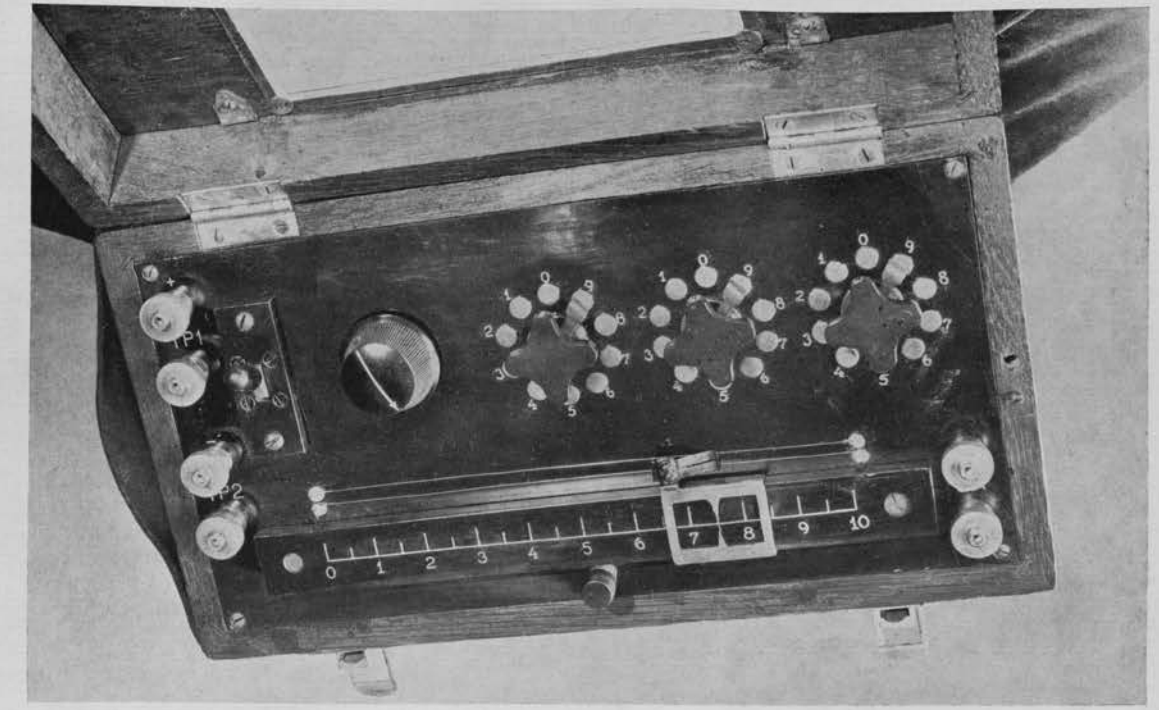

PLATE 1. RADIATION POTENTIOMETER.

ECHINOIDS FROM THE MALUMBANG FORMATION PHILIPPINE ISLANDS

By MERLE C. ISRAELSKY
Of Houston, Texas

FIVE PLATES

Due to the kindness of Dr. R. E. Dickerson, formerly curator of the Department of Palæontology of the California Academy of Sciences, the specimens considered herein were placed at my disposal in the spring of 1923. Various adverse circumstances have prevented earlier completion of the study.

Former Director E. D. Merrill, of the Philippine Bureau of Science, kindly permitted the sending of specimens belonging to that institution.

To Hubert Lyman Clark, I am indebted for several references and a correction in nomenclature.

According to Dr. R. E. Dickerson, the Malumbang formation is lower Pliocene in age.

With the possible exception of *Schizaster pratti* sp. nov., the forms nearest allied to those here figured appear to belong to the living fauna of the western Pacific, which suggests a possibly younger age for the Malumbang formation.

1. CLYPEASTER MALUMBANGENSIS Israelsky, sp. nov. Plate 1, fig. 1.

Test depressed; outline from above roundly pentagonal with margins slightly concave at distal ends of the interambulacra, and slightly convex at distal ends of the ambulacra; margins thin. Within the petalous area the test is moderately arched; flattened from petalous zone to margins. Tubercles numerous, primaries small with sunken areolæ; miliary tubercles very numerous; madreporite circular, ocular and genital pores indistinct in the specimen at hand. Unpaired anterior petal the longest (24.2 mm), paired petals of nearly equal length (about 23.5 mm), all petals broad, short, open at ends. Underside slightly concave from margin to peristome. Periproctal area broken away. Length (estimated), 112 mm; greatest width, 102; height, 12.

Holotype, No. 5216, California Academy of Sciences; plastoholotype, Bureau of Science No. 201; collected by R. E. Dickerson from "Malumbang formation, Philippine Is., Island of Leyte, west coast, 100 meters west of river at San Miguel Barrio, 2 kilometers west of Palompon. Sandstone, dipping NE."

Clypeaster rotundus A. Agassiz,[1] has relatively longer and narrower petals and a thicker margin than the new species. *Clypeaster humilis* Leske[2] is flatter, has longer petals, and is more rounded at the ambitus. The latter species, now living in the East Indian province, is very close to *C. malumbangensis.*

2. CLYPEASTER cf. SCUTIFORMIS Gmelin. Plate 1, figs. 2 to 4.

Laganum multiforme K. Martin var. *tayabum* PRATT and SMITH, Philip. Journ. Sci. § A 8 (1913) pl. 2, fig. 3.

Clypeaster sp. b. DICKERSON, Philip. Journ. Sci. 20 (1922) pl. 13, fig. 4.

The specimen at hand, the same as figured in the above references, is poorly preserved, being but an internal cast. However, it is clearly a *Clypeaster,* and the only apparent difference between it and the specimen figured by A. Agassiz[3] as *Clypeaster scutiformis* Gmelin is that the periproct lies closer to the posterior margin in our specimen. Better preserved material is necessary to determine with certainty whether or not *Clypeaster scutiformis* ranges back into the Malumbang formation.

Length, 48.5 mm; width, 38.2; height, 10.5.

Figured specimen in collection Philippine Bureau of Science, collected by Pratt and Dalburg from "Luzon, Tayabas Province, P. I., Bondoc Peninsula on the hills north of Mount Anuing near the eastern rim of Canquinsa Valley at Bacau. Malumbang Pliocene. 1912."

3. LAGANUM DICKERSONI Israelsky, sp. nov. Plate 2, figs. 1 to 9.

Outline subpentagonal, with margins slightly reëntrant at the interambulacra, length greater than width; greatest width posterior to the extremities to the anterior paired petals; ambitus well rounded, thick. Adoral surface flat, apical system slightly forward of center; madreporite large, roundly pentagonal, with five genital pores; petals lyre-form, reaching well toward the margins and markedly open at distal extremities. Oral surface flat, slightly concave around mouth with oral grooves slightly sunken and reaching about two-thirds the distance toward margin; periproct round or ovate, lying midway between peristome and posterior extremity.

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[1] Clark, H. L., Mem. Mus. Comp. Zoöl. 46 (1914) 38, pl. 128, fig. 6; pls. 132, 133.

[2] Clark, H. L., op. cit. 36, pl. 137; pl. 138, fig. 4.

[3] Illustr. Catal., Mus. Comp. Zoöl. No. 7 (1872–74) pl. 1. 13 f, figs. 1–4.

Measurements of Laganum dickersoni sp. nov.

Collection.	No.	Length.	Width.	Height.
		mm.	*mm.*	*mm.*
California, Academy of Sciences, syntype	5205	38.3	36.2	8.2
Bureau of Science, plastosyntype	203			
California Academy of Sciences, syntype	5206	32.1	29.1	57
Bureau of Science, plastosyntype	204			
California Academy of Sciences, syntype	5207	26.7	22.5	5.3
Bureau of Science, plastosyntype	205			

The relative increase in width with the increase in size is noteworthy. *Laganum dickersoni* differs from *Laganum laganum* (Leske)[4] in having more open petals and a relatively smaller peristome and periproct. The open petals seem quite distinctive. The species is named for Dr. R. E. Dickerson, who supplied the specimens herein considered.

Collected by A. Krystofovich from "Philippine Is., northern Luzon, Cagayan, municipality of Peñablanca, Lagum, between the junction of the rivers Pinnacanauan and Nattelag; abundant fauna of pelecypods, gastropods, and echinoids, as well as corals. Aug. 18, 1921."

4. **LAGANUM EQUÆPETALA** Israelsky, sp. nov. Plate 2, figs. 10 to 12.

Outline subcircular, margin swollen, forming a rim; apical system central with four genital pores; petals equal in length (5.6 mm); oral side slightly concave, peristome circular, periproct at inner edge of rim, transversely elliptical, tubercles over whole of test, largest on swollen margin. Length, 19.9 mm; width, 18.3; height, 4.8.

Holotype in collection of Philippine Bureau of Science, collected by Pratt and Dalburg from "Luzon, Tayabas Province, P. I., Bondoc Peninsula, on the hills north of Mount Anuing, near the eastern rim of Canquinsa at Bacau. Malumbang Pliocene."

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[4] Agassiz, Louis, Mon. Scutelles (1841) 108, pl. 22, figs. 25–27; pl. 23, figs. 8–12. Figured as *Laganum bonani* Klein. H. L. Clark kindly supplied this nomenclatorial correction.

This species is distinguished from *Laganum orbiculare* Leske[5] by its equal-lengthed petals, relatively greater height, and thicker margin. *Laganum orbiculare* has been reported by Herklots[6] from the Tertiary of Java, and he justly remarks that his form is closer to the variety *marginale*[7] Agassiz than to typical *orbiculare*.[8] His measurements are "diameter antero-posterior 24‴ transversal 21‴, hauteur du sommet 5.5‴ du bord 2‴." From these it is readily seen that the new species is much more nearly circular in outline than Herklots's specimen.

5. LAGANUM cf. DECAGONALE Lesson. Plate 1, fig. 5.

A rather imperfect specimen which seemingly closely resembles *Laganum decagonale* as figured by de Meijere.[9] Length, 35 mm; width, 28.9; height, 5.1.

Plesiotype No. 5200, California Academy of Sciences; platoplesiotype, Bureau of Science No. 206; locality not known.

6. PERONELLA MERRILLI Israelsky, sp. nov. Plate 2, figs. 17 to 19.

Clypeaster sp. a DICKERSON, Philip. Journ. Sci. 20 (1922) pl. 13, figs. 3*a*, 3*b*.

Outline broadly subelliptical, slightly narrowed posteriorly, margin gently inflated, apex low; apical system somewhat forward of center with four genital pores; petals reach over one-half way to margins, nearly equal in length; oral surface but slightly concave; peristome circular, forward of center, furrows obscure, periproct circular and about twice its diameter from the posterior margin. Length, 30.7 mm; width, 26; height, 4.5.

Holotype, No. 5209, California Academy of Sciences; plastoholotype, Bureau of Science No. 207; collected by E. W. McDaniel and Roy E. Dickerson from "Philippine Is. Luzon, Tayabas Province, Bondoc Peninsula, west side Ragay Gulf, two and three fourths kilometers northwest of Bureau of Lands Bench Mark No. 1, in coarse sandstone (coral and shell sand) dipping 12 ° S, strike N. 50 ° W."

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[5] De Meijere, Siboga-Expeditie, Echinoidea 43 (1904) 126, pl. 6, figs. 69, 73–75.

[6] Herklots, J. A., in Junghuhn, Fossiles de Java, Echinodermes, pt. 4. Leide (1854).

[7] Agassiz, Louis, Mon. Scutelles (1841) 121, pl. 22, figs. 11–15.

[8] Agassiz, op. cit. 120, pl. 22, figs. 16–20.

[9] De Meijere, Siboga Expeditie, Echinoidea 42 (1904) 11, pl. 6, figs. 58–62.

The new species is much more elongated and less inflated at the margin than is *Laganum orbiculare* Leske.[10] Named for former Director E. D. Merrill, by whose permission the specimens belonging to the Philippine Bureau of Science were made accessible for study.

7. PERONELLA RAGAYANA Israelsky, sp. nov. Plate 2, figs. 13 to 16.

Outline of test nearly circular, slightly longer than wide, adoral surface gently concave from margin to apex, apical system slightly forward of center, with four genital pores at the head of the paired ambulacra, petals widely open proximally, reaching over half way to margin from apex, odd anterior slightly longer than the anterior paired petals, but shorter than the posterior pair. Underside slightly concave, peristome round, slightly forward of center, periproct round, about twice its diameter from edge.

Measurements of Peronella ragayana sp. nov.

Collection.	No.	Length.	Width.	Height.
California Academy of Sciences, holotype	5212	[a] 38.0	[a] 34.0	6.6
California Academy of Sciences, paratype	5213	12.0	11.3	2.2
Bureau of Science, plastoholotype	208			

[a] Estimated.

Collected by E. M. McDaniel and Roy E. Dickerson from "Philippine Is., Tayabas Province, Bondoc Peninsula, west side of Ragay Gulf, two and three fourths kilometers northwest of Bureau of Lands Bench Mark No. 1, in coarse sandstone (coral and shell) dipping 2° S. Strike N. 50° W."

The species here described has a marked resemblance adorally to *Peronella pellucida* Doderlein[11] but that species has shorter petals and the periproct is more distant from the margin.

8. SCHIZASTER PRATTI Israelsky, sp. nov. Plate 4, figs. 2, 3; Plate 5, figs. 1 to 4.

Schizaster subrhomboidalis Herklots, PRATT and SMITH, Philip. Journ. Sci. § A 8 No. 5 (1913) pl. 2, fig. 5.

Schizaster subrhomboidalis Herklots, DICKERSON, Philip. Journ. Sci. 20 No. 2 (1922) pl. 13, figs. 5*a*, 5*b*. Not *Schizaster subrhomboidalis* Herklots, J. A. HERKLOTS in Junghuhn, Fossiles de Java, Echinodermes, pt. 4. Leide 5 (1859) 20, fig. 4.

Test ovoid, highest in odd posterior interambulacrum and narrowed in the same area; apical system posterior to center (detail obliterated), petals deeply sunken, the odd anterior groove passing under the ambitus to the peristome; anterior paired petals reach half way to ambitus, straight except in immediate proximity to the apical system, posterior petals short, forming an acute angle; posterior interambulacrum ridged; plastron broad; peristome semilunar with strong posterior lip, periproct well up on posterior truncation just below termination of ridge.

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[10] Agassiz, Louis, Mon. Scutelles (1841) 120, pl. 22, figs. 16–20.

[11] Doderlein, Arch. f. Naturg. (1885) 51, Jahrgang, pt. 1, p. 104. H. L. Clark, Mem. Mus. Comp. Zoöl. 46 (1914) 53, pl. 42, figs. 1, 8, 9, 10.

Measurements of Schizaster pratti sp. nov.

Collection.	Length.	Width.	Height.
Bureau of Science, cotype A	60.7	57.5	43.2
Bureau of Science, cotype B	51.6	48.5	36.0

Collected by Pratt and Dalburg from "Luzon, Tayabas Province, P. I., Bondoc Peninsula on the hills north of Mount Anuing near the eastern rim of the Canquinsa Valley at Bacau. Malumbang Pliocene. 1912."

This species compares very closely with *Schizaster progoensis* Gerth[12] from the Upper Miocene of Java, but differs from it in that the dorsal slope is much steeper and the apical system is relatively more anterior. Named for Mr. Wallace E. Pratt, in recognition of his geologic work in the Philippines.

9. PERICOSMUS SCHENCKI Israelsky, sp. nov. Plate 3, figs. 1 and 2; Plate 4, fig. 1.

Test large, thick shelled; outline broadly elliptical; apical system forward of center, odd anterior ambulacrum but slightly depressed, the paired ambulacra well sunken, narrow and approximately equal in length, apical system obscure in specimen at hand; peripetalous fasciole enters interradia; traces of marginal fasciole discernible; peristome well forward, periproct transversely elliptical. Actual measurements of the crushed specimen are: Length, 120 mm; breadth, 112; height, 63.

Holotype, No. 5217, California Academy of Sciences plastoholotype, Bureau of Science No. 202; collected by R. E. Dickerson and E. W. McDaniel from "Philippine Is., Luzon, Tayabas Province, Bondoc Peninsula, west side of Ragay Gulf, 2.75 kilometers northwest of Bureau of Lands Bench Mark No. 1, in coarse sandstone (coral and shell sand) dipping 12° S., strike North 50° West."

[12] Gerth, H., in K. Martin, Samm. Geol. Reichs-Mus. Leiden, Neue Folge, Bd. 1, 2te Abt., Heft 4 (1922).

The large size of the species is noteworthy. The peripetalous fasciole in *Pericosmus macronesius* Koehler[13] is much more angulated than in this species. This species is named for Dr. H. G. Schenck, in recognition of his work on Philippine geology.

10. SPATANGID sp. indeterminate, A.

Schizaster subrhomboidalis PRATT and SMITH, Philip. Journ. Sci. § A 8 (1913) pl. 3, fig. 4. Not *Schizaster subrhomboidalis* HERKLOTS, in Junghuhn, Fossiles de Java, Echinodermes, pt. 4. Leide 5 (1859) 20, fig. 4.

Figured specimen in collection of the Philippine Bureau of Science. Collected by Eveland and Smith from "Limestone ridge 2 kilometers west of the city hall and north of the Weather Observatory, Baguio. This is the upper limestone in the Benguet district."

11. SPATANGID sp. indeterminate, B.

Schizaster subrhomboidalis SMITH, Philip. Journ. Sci. § A 8 (1913) 291, pl. 19, fig. 1. Not *Schizaster subrhomboidalis* Herklots, J. A. HERKLOTS, in Junghuhn, Fossiles de Java, Echinodermes, pt. 4. Leide 5 (1859) 20, fig. 4.

Figured specimen in collection of the Philippine Bureau of Science. Collected by W. D. Smith from "Minanga River, white cliffs near camp 1, Cebu Province in limestone rubble."

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[13] Koehler, Echinoderma of the Indian Museum, pt. 8, Echinoidea (1), Calcutta (March, 1914) 133, pl. 12, figs. 1-5.

ILLUSTRATIONS

PLATE 1

[Figures natural size.]

FIG. 1. *Clypeaster malumbangensis* Israelsky, sp. nov., holotype, No. 5216, California Academy of Sciences type collection; adoral view.
2. *Clypeaster* cf. *scutiformis* Gmelin; figured specimen, Philippine Bureau of Science collection; adoral view.
3. Same as fig. 2, oral view.
4. Same as fig. 2, side view.
5. *Laganum* cf. *decagonale* Lesson; figured specimen, plesiotype, No. 5208, California Academy of Sciences type collection; adoral view.

PLATE 2

[Figures natural size, except as noted.]

FIG. 1. *Laganum dickersoni* Israelsky, sp. nov., syntype, No. 5205, California Academy of Sciences type collection; adoral view.
2. Same as fig. 1; oral view.
3. Same as fig. 1; side view.
4. *Laganum dickersoni* Israelsky, sp. nov., syntype, No. 5206, California Academy of Sciences type collection; adoral view.
5. Same as fig. 4; oral view.
6. Same as fig. 4; side view.
7. *Laganum dickersoni* Israelsky, sp. nov., syntype, No. 5207, California Academy of Sciences type collection; adoral view.
8. Same as fig. 7; oral view.
9. Same as fig. 7; side view.
10. *Laganum equæpetala* Israelsky, sp. nov., holotype, Philippine Bureau of Science collection; adoral view, × 2.
11. Same as fig. 10; oral view, × 2.
12. Same as fig. 10; side view, × 2.
13. *Peronella ragayana* Israelsky, sp. nov., paratype, No. 5213, California Academy of Sciences type collection; adoral view, × 2.
14. Same as fig. 13; oral view, × 2.
15. *Peronella ragayana* Israelsky, sp. nov., holotype, No. 5212, California Academy of Sciences type collection; adoral view.
16. Same as fig. 15; side view.
17. *Peronella merrilli* Israelsky, sp. nov., type, No. 5209, California Academy of Sciences type collection; adoral view.
18. Same as fig. 17; oral view.
19. Same as fig. 17; side view.

PLATE 3

[Figures natural size.]

FIG. 1. *Pericosmus schencki* Israelsky, sp. nov., holotype, No. 5217, California Academy of Sciences type collection; adoral view.
2. Same as fig. 1; side view.

PLATE 4

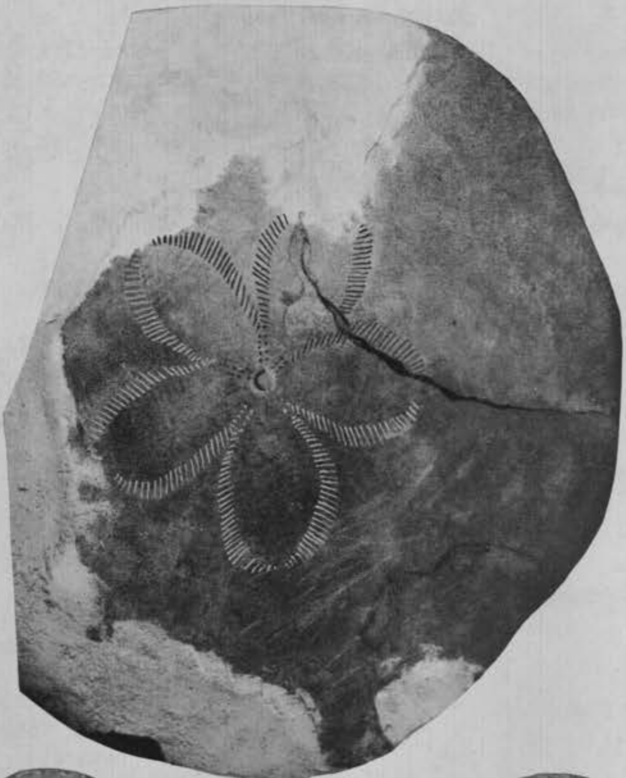
[Figures natural size.]

FIG. 1. *Pericosmus schencki* Israelsky, sp. nov., holotype, No. 5217, California Academy of Sciences type collection; oral view.
2. *Schizaster pratti* Israelsky, sp. nov., cotype A, Philippine Bureau of Science collection; adoral view.
3. *Shizaster pratti* Israelsky, sp. nov., cotype B, Philippine Bureau of Science collection; adoral view.

PLATE 5

[Figures natural size.]

FIG. 1. *Schizaster pratti* Israelsky, sp. nov., cotype B, Philippine Bureau of Science collection; oral view.
2. Same as fig. 1; side view.
3. Same as fig. 1; rear view.
4. Same as fig. 1; front view.



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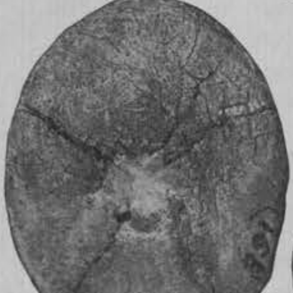

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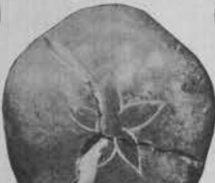

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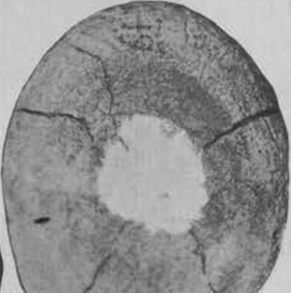

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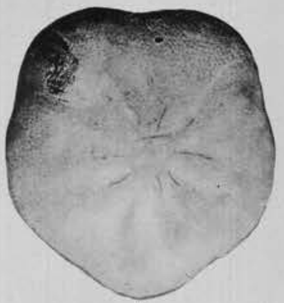
PLATE 1.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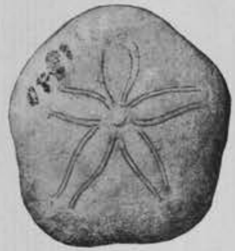
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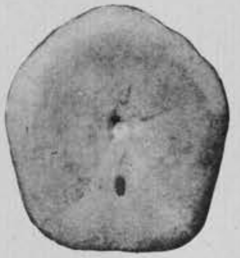
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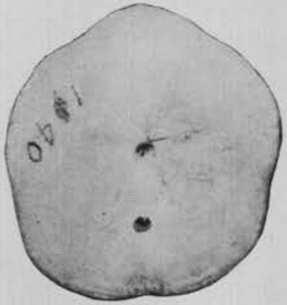

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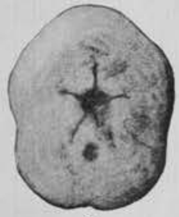
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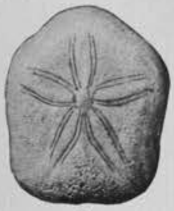
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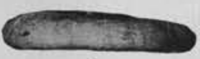
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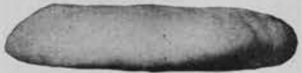
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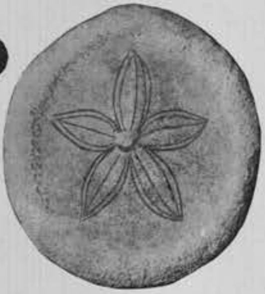
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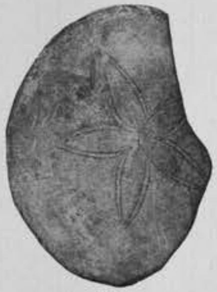
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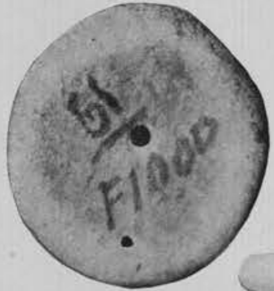

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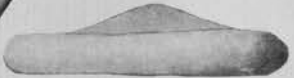
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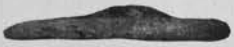
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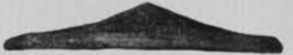
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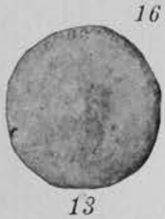
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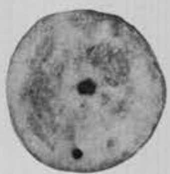
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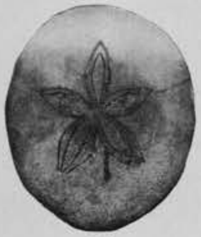
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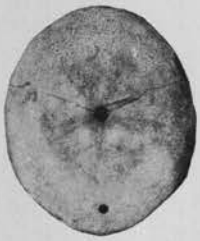
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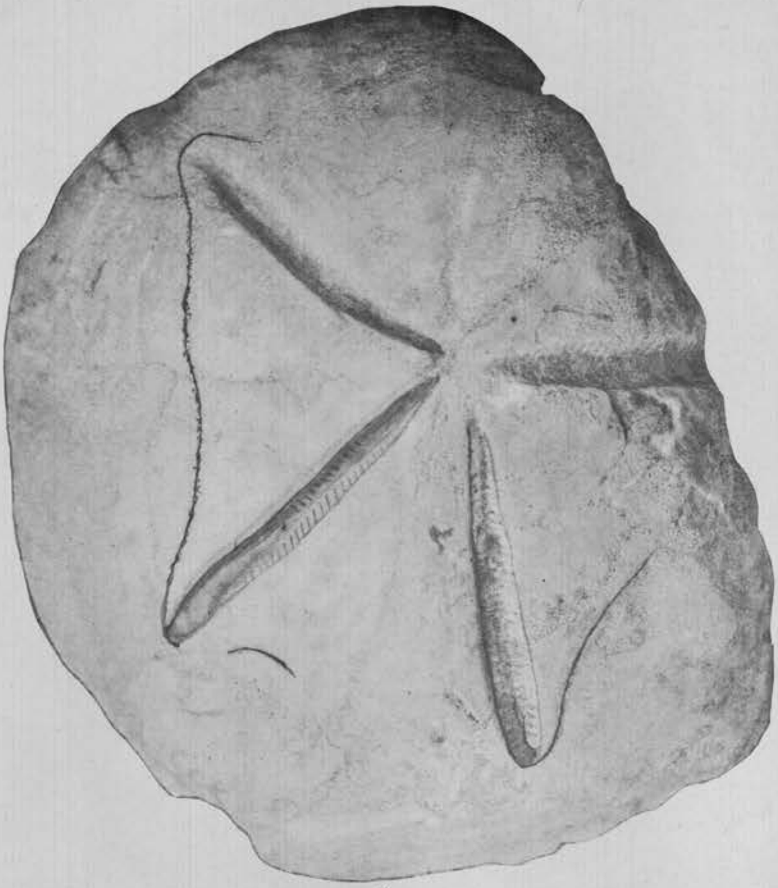
PLATE 2.



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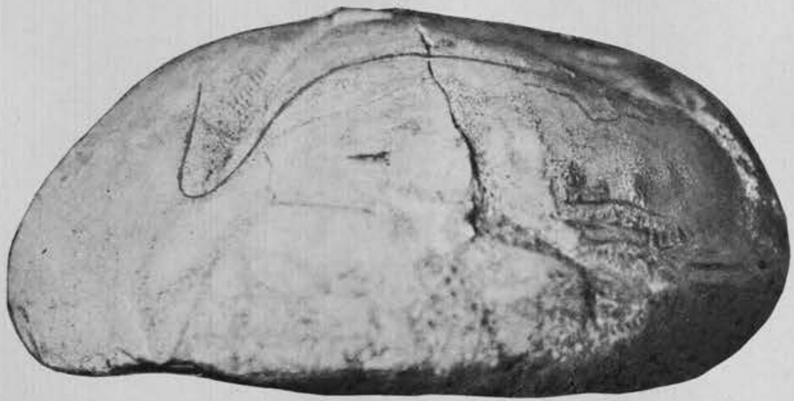

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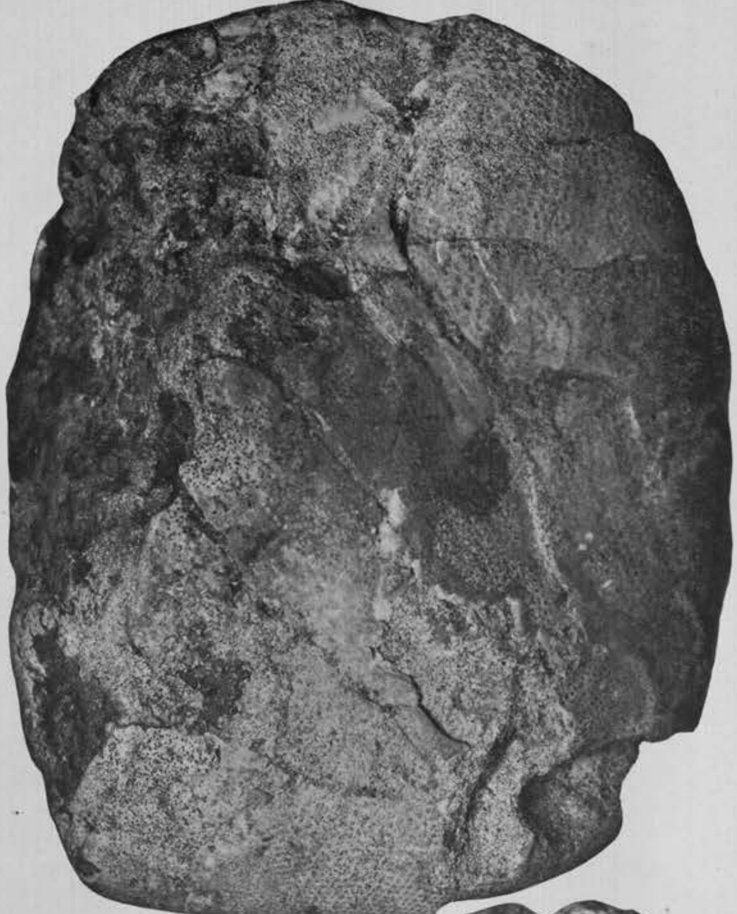

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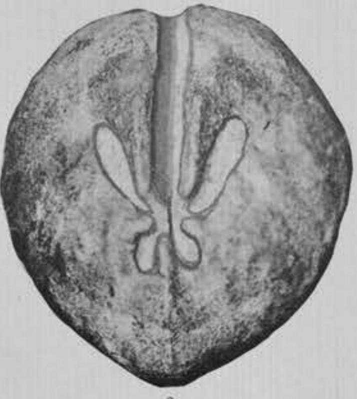

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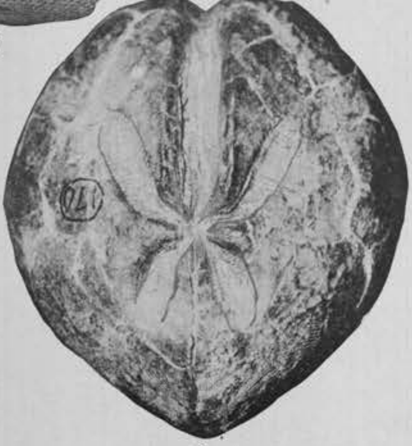

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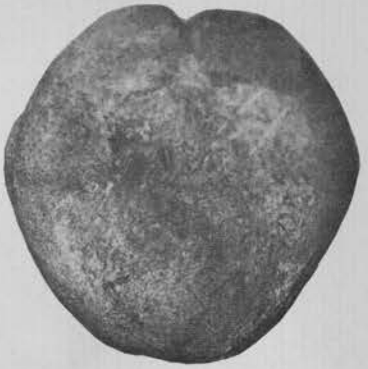
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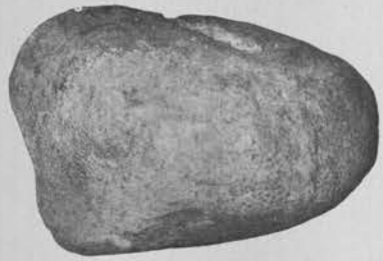
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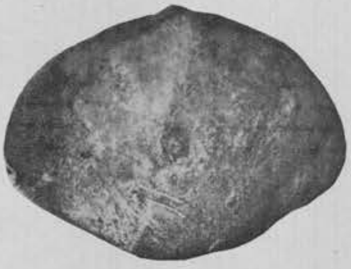
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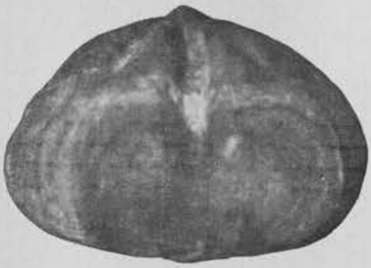
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PLATE 5.

DIE HOPLIONOTA-ARTEN VON DEN PHILIPPINEN-INSELN (COLEOPTERA; CHRYSOMELIDÆ)

Von Franz Spaeth

Vienna, Austria

EIN TEXT FIGUR

Als ich die Gattung *Hoplionota* vor zwanzig Jahren zum ersten Male zusammenfassend bearbeitete, waren von den Philippinen-Inseln nur 6 Arten bekannt; seitdem hat sich ihre Zahl auf 25 erhöht; dies ist in erster Linie ein Verdienst des leider viel zu früh verstorbenen Ch. F. Baker, des unermüdlichen Erforschers der Fauna dieser Inseln.

Da die erschienenen Einzelbeschreibungen vielleicht die Unterschiede nicht immer leicht erkennen lassen, habe ich hier die Form einer analytischen Tabelle gewählt.

Zur Beschreibung der gerade bei *Hoplionota* besonders wichtigen Skulptur der Flügeldecken habe ich die in der eingangs zitierten Arbeit vorgeschlagenen Bezeichnungen gewählt und füge zu deren besseren Verständnis bei:

Im allgemeinen sind auf jeder Flügeldecke zwei Längsrippen und zwei oder drei Querleisten, ferner eine Anzahl Höcker oder auch Dorne vorhanden, die sich aus dem seinerzeitigen Flügelgeäder und seinen Verästungs-Stellen ableiten lassen.

Die innere Längsrippe nannte ich Dorsalrippe, *D*, die äussere, über die Schulterbeule laufende: Humeralrippe, *H;* letztere ist vorn meist winklig nach aussen gebogen, seltener gegabelt. Von den Querleisten läuft eine nahe hinter oder auch in der Mitte; sie ist die Mittelleiste und zerfällt in den äusseren Teil zwischen dem Scheibenrand und der Dorsalrippe; diesen Teil nannte ich Pontalleiste, *P*, den anderen zwischen Dorsalrippe und Naht: Suturalleiste, *S;* die zweite Querleiste liegt auf dem Abfall, sie heisst Spitzen oder Apikalleiste, *A;* seltener ist hinter ihr noch eine dritte Querleiste: die Postapikalleiste, *PA;* die Apikalleiste, *A*, setzt sich zuweilen über die Dorsalrippe nach innen fort; aussen reicht sie meist bis zu einem kleinen Höcker, an dem sie sich in mehrere Aeste gabeln kann. Einer dieser Aeste geht nach hinten zum Scheibenrand: es ist die costa terminalis, *Ct*, der zweite gerade oder schräg auswärts: die furca externa, *Fe;* der dritte entweder gerade nach vorn oder mehr nach innen auf den Haupthöcker gerichtet: die furca interna, *Fi;* endlich geht oft ein kleiner Ast noch vor dem Marginalhöcker nach hinten: die costa ultima, *Cu;* häufig ist diese isoliert und bildet einen kleinen Höcker. Von den Höcker oder Dornen stehen normal vier in der Dorsalreihe: der Basalhöcker, *1*, an der Basis, der Postbasal, *2*, hinter ihm, oft sehr klein; die Dorsalreihe ist zwischen diesen beiden Höckern meist niedrig, oft auch ganz unterbrochen; in oder hinter der Mitte folgt der Haupthöcker, *3*, fast immer der höchste und grösste von allen, an der Kreuzungsstelle der Dorsalrippe mit der Mittelleiste. Meist treffen der vordere und der rückwärtige Teil der Dorsalrippe die Mittelleiste in demselben Punkte, so dass sich nur ein gemeinsamer Schnittpunkt ergibt; oft aber trifft der vordere Teil die Mittelleiste weiter aussen (nur bei den Arten aus Neu—Guinea und Australien weiter innen) als der rückwärtige, so dass zwei Schnittpunkte vorliegen.

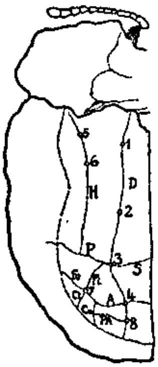

FIG. 1. Skulptur der Flügeldecken der *Hoplionota.*

Der vierte Höcker der Dorsalreihe ist der Apikalhöcker, *4*, am Schnittpunkt der Dorsalrippe mit der Spitzenleiste; er ist fast immer viel kleiner als der Haupthöcker, fehlt aber ebenfalls nur selten; ganz ausnahmsweise steht auch noch ein fünfter Höcker in der Dorsalreihe, am Schnittpunkt mit der Postapikalleiste: der Postapikalhöcker, *8*.

Auf der äusseren Rippe können vorn zwei Höcker stehen: der Humeral, *5*, und hinter ihm der Posthumeral, *6*.

Als letzter erübrigt noch der schon erwähnte Marginalhöcker, *7*, an der Stelle, wo sich die Apikalleiste und ihre Anhänge gabeln.

Selbstverständlich gibt es keine *Hoplionota,* die alle diese Skulpturen aufweist; im allgemeinen sind die Dorsalrippe und die Mittelleiste meist kräftiger als die anderen; ebenso ist der Haupthöcker mit wenigen Ausnahmen gut entwickelt, während die anderen Höcker, insbesonders jene der Humeralreihe oft erlöschen.

Die beiliegende schematische Zeichnung kann vielleicht zum besseren Verständnis der obigen Bezeichnungen beitragen.

Tabelle der Hoplionota-Arten von den Philippinen.

1 (8). Die Höcker der Dorsalreihe fehlen vollständig; insbesonders ist der Haupthöcker auch nicht einmal angedeutet, da die Dorsalrippe ohne Höhendifferenz über seine Stelle hinwegführt und nicht von der Mittelleiste geschnitten wird; von den Querleisten sind höchstens einzelne Reste erkennbar.

2 (5). Auf jeder Flügeldecke sind zwei schwarze Flecke. Querleisten fehlen ganz.

3 (4). Die beiden schwarzen Flecke liegen an der Naht, der erste an der Basis, der zweite in der Mitte. Rötlichgelb. Die Dorsalrippe ist gleichmässig schmal, niedrig, an der Postbasalstelle einwärts, an der des Haupthöckers auswärts gebogen; die Humeralrippe ist vorne schwach und dort, wo sie sich mit der (fehlenden) Pontalleiste schneiden würde, im Winkel gebrochen. 7.75 bis 6 mm. LUZON, Manila. Verh. zool. bot. Ges. 64 (1914) 298 .... *H. braueri* Sp.

4 (3). Die schwarzen Flecke sind quer, der vordere innen verschmälert, von der vorletzten Punktreihe bis über die Dorsalrippe ausgedehnt, der rückwärtige, noch breiter, bildet eine Querbinde von der zweiten bis zehnten Punktreihe. Die Dorsalrippe ist "fast" gerade, die Humeralrippe hinter der Mitte nach aussen gebogen und bald erlöschend. 8 mm. LUZON, Tayabas. Deutsch. Ent. Zeit. (1915) 508.......... *H. quadrisignata* Wse.

Mir unbekannt; vielleicht von der vorigen nicht als Art verschieden. Typus jetzt vermutlich im Museum Stokholm.

5 (2). Die Flügeldecken sind ohne schwarze Flecke, nur mit wenig dunklerer, wischförmiger Zeichnung; die Querleisten sind stellenweise schwach vorhanden.

6 (7). Die Dorsalrippe ist von der Basis bis zur Spitze gerade und von gleicher Stärke, die Humeralrippe viel schwächer, an der Basis und hinter der Mittelleiste erloschen, die Mittel und Spitzenleiste nur aussen von der Humeralrippe erkennbar. Bräunlichgelb, oben wenig dunkler, ein breiter Basalast auf dem Seitendach und eine mit ihm zusammenhängende Längsbinde zwischen Randstreif und Humeralrippe hellbraun; zwischen Dorsal- und Humeralrippe ist ein hellerer Fleck, der beiläufig von der Mittel- bis zur Spitzenleiste reicht. Lang-eiförmig, hinter der Schulter am breitesten. 9 bis 7 mm. MINDANAO, Dapitan. Deutsch. Ent. Zeit. (1915) 508.......... *H. bakeri* Wse.

7 (6). Die Dorsalrippe ist zwischen den Stellen des Basal- und Postbasalhöckers niedrig, fast unterbrochen und nach innen gebogen. Die Humeralrippe bildet mit der Pontalleiste einen unbedeutenden Höcker und ist dann kurz völlig unterbrochen; ihr hinterer Teil ist S-förmig gebogen und wird vom inneren Teile der Spitzleiste weiter hinten als vom äusseren Teil berührt.

Voderecken des Halsschildes mehr verrundet. Scheibe der Flügeldecken mit einer schwärzlich-braunen, wenig auf das Seitendach übergreifenden, innen von der Humeralrippe, hinten von der Apikalleiste begrenzten Langsbinde. 5.5 mm. MINDANAO, Butuan. Deutsch. Ent. Zeit. (1915) 509; mir unbekannt.
H. persimplex Wse.

8 (1). Die Stelle des Haupthöckers ist erkennbar, entweder durch einen Höcker oder mindestens dadurch, dass sich die Dorsalrippe und die Mittelleiste hier schneiden; auch sonst sind Höcker oder Kreuzungsstellen von Rippen und Leisten vorhanden.

9 (12). Längsrippen fehlen; die Höcker stehen isoliert, ohne Verbindung.

10 (11). Umriss kurz rechteckig; Oberseite rostrot, mit pechschwarzen Erhöhungen; das Seitendach hinter der Mitte unscharf lebhafter rot. Alle Höcker sind niedrig; in der Dorsalreihe vier, hievon der Haupthöcker länger, aber nicht höher, schmal; in der Humeralreihe sind vier Erhöhungen; die erste wird durch die Schulterbeule und die damit zusammenhängende Anfangskrümmung der Humeralrippe gebildet, die zweite durch den gebogenen Aussenteil der Pontalleiste. Die dritte ist quer und ein Rest der furca externa, die vierte knopfförmig und dürfte von der costa ultima übriggeblieben sein. 5.5 bis 4.5 mm. MINDANAO, Dapitan. Philip. Journ. Sci. 18 (1921) 721.
H. dapitana Sp.

11 (10). Umriss gerundet. Oberseite schwarz mit rostrotem Saum. Die Skulptur der Flügeldecken dieser mir unbekannten scheint der der vorigen Art ähnlich zu sein, doch erwähnt Weise ausser vier Höckern in der Humeralreihe, die jenen der *dapitana* entsprechen würden, noch ein Höckerchen schräg hinten und aussen vom dritten Höcker. Seitenrand aufgebogen, höher und dicker als gewöhnlich. 4 mm. PALAWAN, Puerto Princesa. Philip. Journ. Sci. 18 (1921) 511.................... *H. granulosa* Wse.

12 (9). Es sind Längsrippen vorhanden; allfällige Höcker stehen daher nicht isoliert.

13 (16). Die furca interna fehlt vollständig. Fühler ziemlich lang, bis über die Halsschild-Ecken reichend; die Humeralrippe ist vorne nicht winklig nach aussen gebogen, bis zur Pontalleiste sehr niedrig.

14 (15). Der Haupthöcker ist sehr niedrig und tritt kaum aus der Dorsalrippe heraus; letztere ist zwischen ihm und dem Apikalhöcker fast gleich hoch, also nicht ausgerandet; auch der Apikalhöcker ist sehr klein, noch schwächer als der Haupthöcker. Die Suturalleiste ist sehr schräg nach vorne gerichtet, so dass sie mit der Naht einen Winkel von etwa 45° bildet. Bräunlichgelb, auf den Flügeldecken je zwei pechschwarze Punkte, einer an der Basis zwischen Schulterbeule und Randstreif, unscharf, der andere quer, auf dem Haupthöcker und der Pontalleiste; ausserdem ist ein unscharfer Wisch innen auf dem Seitendach hinter der Brücke. Der Basalhöcker ist länger und niedriger, der Postbasal viel weniger deutlich als bei *modesta*. 6.5 bis 5.5 mm. MINDANAO, Surigao. Philip. Journ. Sci. 28 (1925) 582.
***H. formosa* Sp.**

15 (14). Der Haupthöcker tritt deutlich aus der Dorsalrippe heraus, letztere ist zwischen ihm und dem Apikalhöcker eingesenkt, ausgerandet; der Apikalhöcker, sowie die vorderen zwei Höcker sind höher als bei der vorigen Art. Die Suturalleiste geht vom Haupthöcker zur Naht nur wenig nach vorne, so dass sie diese fast unter einem rechten Winkel trifft; der Haupthöcker liegt viel wieter aussen als die anderen der Dorsalreihe. Hell wachsgelb, stark glänzend, die Flügeldecken entweder einfärbig (ab. *nitida* Wse., l. c., p. 511) oder das Seitendach hinter der Mitte mit einer schmalen, wenig dunkleren Binde (Nominatform) oder die Scheibe ausserdem noch mit einem pechbraunen Punktfleck an dem rückwärtigen, äusseren, ausgehöhlten Absturz des Haupthöckers (nicht auf diesem!) [ab. *chapuisi* Sp., Verh. Zool. Bot. Ges. (1913) 523]. 6 bis 5 mm. LUZON, Manila; Los Baños, Mount Maquiling; Rizal, Mount Irid. Mitt. Münch. Ent. Ver 5 (1881) 20.. *H. modesta* Wagen.

16 (13). Die furca interna ist noch vorhanden, mindestens rudimentär.

17 (34). Der vordere Teil der Dorsalrippe trifft die Mittelleiste weiter aussen als der innere, sie haben also verschiedene Schnittpunkte.

18 (27). Die furca interna geht nach vorne fast parallel zum rückwärtigen Teil der Dorsalrippe und trifft die Pontalleiste weit aussen vom Haupthöcker oder ist kurz vorher abgekürzt; sie bildet fast die Fortsetzung der Humeralrippe.

19 (20). Die furca interna ist vor der Pontalleiste abgekürzt. Oberseite blassgelb, die Scheibe der Flügeldecken gesättigter, braungelb, eine breite, schwarzbraune Längsbinde lässt an der Basis nur den ersten Streif und den letzten Zwischenraum frei, verengt sich dann kurz auf den Raum zwischen dem 5. und 7. Streif, erweitert sich innen wieder bis an den (gelben) Dorsalkiel, überdeckt die Haupthöckerstelle und die Mittelleiste, sowie die aussen von der furca interna gelegene Partie, erreicht hiebei den Rand der Scheibe, wobei sie auf das Seitendach eine breite, abgekürzte, heller braune Binde sendet, und bildet schliesslich einen grossen Fleck auf und hinter der Apikalleiste bis an die Naht. Umriss schmal rechteckig; alle Höcker nur angedeutet; von der Humeralrippe ist nur die Anfangskurve vorhanden. Fühlerkeule sehr kurz und dick. 5.5 bis 4.5 mm. BOHOL. Wagener, Mitt. Münch. Ent. Ver. 5 (1881) 19; Spaeth, Philip. Journ. Sci. 18 (1921) 727..................... *H. vittata* Wagen.

20 (19). Die furca interna erreicht die Mittelleiste. Die Zeichnung der Flügeldecken ist anders.

21 (24). Flügeldecken wenigstens auf einzelnen Höckerstellen schwarz gefleckt.

22 (23) Umriss schmäler rechteckig. Die ganze Mittel- und Spitzenleiste, sowie die Anhänger der letzteren sind mit ihren beiderseitigen Abstürzen schwarz; ebenso der Basal-, Postbasal- und Humeralhöcker; auch die Krümmung der Humeralrippe dürfte mitunter schwarz werden, da sie beim Typus etwas dunkler als ihre Umgebung ist. Oberseite gelblichrot, das Seitendach vor

der Mitte mit einer wenig helleren, unscharfen, am Rande verbreiterten glashellen Makel........................ *H. cavillata* sp. nov.[1]

23 (22). Umriss breiter rechteckig, verhältnismässig kürzer. Oberseite hellrot, auf jeder Flügeldecke sind nur zwei schwarze Querflecke, der vordere auf der Mittel-, der zweite auf der Spitzenleiste, beide zwischen den Längsrippen und noch über deren Schnittpunkte mit den Querleisten hinausreichend. Seitendach ohne Zeichnung. Die vier Höcker der Dorsalreihe ragen über die Rippe deutlich hinaus, obwohl sie niedrig sind. Annähernd rechteckig, mit der grössten Breite erst kurz vor der Mitte der Flügeldecken. Seiten des Halsschildes nach vorne etwas schräg verengt, die (falschen!) Vorderecken mehr zugerundet. 6.75 bis 6 mm. NEGROS, Cuernos Mountains. Philip. Journ. Sci. 28 (1925) 583 .... *H. negrosia* Sp.

24 (21). Flügeldecken ohne schwarze Flecke. Die Schnittpunkte in der Dorsalreihe ragen nicht über die Rippe heraus, es fehlen daher hier die Höcker.

25 (26). Die Humeralrippe ist vorne schwach winkelig auf den 8. Zwischenraum nach aussen gebogen. Umriss kürzer und breiter, nach hinten mehr verengt. Oberseite dunkel blutrot, Halsschild, Schildchen und Seitendach etwas heller blutrot. Seiten des Halsschildes nach vorne mehr schräg, mit breiten, verrundeten

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[1] *Hoplionota cavillata* sp. nov. Ziemlich breit, rechteckig, an der Seite kaum erweitert, wenig glänzend, gelblich rot, nur das Seitendach vorne etwas heller und die erhabenen Stellen der Flügeldecken pechschwarz. Fühler ziemlich kurz, nicht bis zu den Hinterecken des Halsschildes reichend; die vier Endglieder der Keule sind dicker als lang. Kopfplatte vor die Augen ziemlich vorgezogen, aber nicht erweitert, vorne zugerundet. Halsschild doppelt so breit als lang, die Seiten vor den rechtwinkeligen Hinterecken zuerst ganz kurz senkrecht zur Basis, dann in gleichmässigem Bogen schräg nach vorne gebogen; der Kopfausschnitt tief, dreieckig, die Scheibe glatt, mit zwei Quereindrücken, von denen der vordere kaum, der rüchwärtige tiefer punktiert ist; die Querfalte zwischen beiden ist flach. Flügeldecken an der Basis kaum breiter als der Halsschild, mit wenig gerundeten, ganz vorne breitesten Seiten. Die Scheibe mit groben Punktstreifen und niedrigen, aus den Rippen kaum herausragenden Höckern; die Dorsalrippe ist zwischen dem 1. und 2. Höcker unterbrochen, die Humeralrippe vor der Pontalleiste undeutlich, vorne auf den 8. Zwischenraum winkelig nach aussen gebogen; der vordere Ast der Dorsalrippe schneidet die Pontalleiste etwas mehr aussen als der rückwärtige; die furca interna verläuft zu dem letzteren fast parallel und bildet eine fast geradlinige Fortsetzung der Humeralrippe; die Suturalleiste geht quer und endet im 2. Streif. Seitendach auf dem hyalinen Fleck geglättet. 5.25 bis 4.5 mm.

In der Körperform der *H. taeniata* verwandt, aber an dem Verlauf der furca interna und den viel niedrigeren, kaum angedeuteten Höckern leicht zu erkennen.

Das einzige Stück in der Sammlung des Herrn W. Schultze trägt die Etikette: MINDORO, Mansalay, E. Taylor."

(falschen) Vorderecken. Die Suturalleiste geht sehr schräg nach vorne zur Naht. 6.25 bis 5.25 mm. SIBUYAN. Philip. Journ. Sci. 28 (1925) 579.. *H. sibuyana* Sp.

26 (25). Die Humeralrippe ist kaum bemerkbar, geht aber vorne ohne Bruch zur Schulterbeule. Umriss länger und schmäler, annähernd rechteckig, aber hinter der Schulter am breitesten, dann schwach verengt und hinten abgestutzt. Oberseite hell gelbrot, das Seitendach vor der Mitte mit einer am Rande breiteren, glashellen, aber unscharfen Makel. Seiten des Halsschildes zuerst senkrecht zur Basis, an den verrundeten (falschen) Vorderecken fast rechtwinkelig gebogen.... *H. schultzei* sp. nov.[1]

27 (18). Die furca interna ist entweder stark abgekürst oder gegen den Haupthöcker, bezw. nach innen gerichtet, ohne ihn zu erreichen. Seitendach immer einfärbig.

28 (29). Oberseite einfärbig rostgelb, Vor- und Seitendach kaum heller, letzteres an der Basis unscharf gesättigter. Die Kreuzungsstellen sind gar nicht höher; alle Rippen und Leisten niedrig, schmal, kaum herausgehoben; die Humeralrippe ist fast erloschen, vorne ohne Aussenkrümmung; die Apikalleiste setzt sich nach innen nicht über die Dorsalrippe fort. Umriss rechteckig, hinten kaum verengt; hiedurch, ferner durch helle Färbung,

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[1] *Hoplionota schultzei* sp. nov. Ziemlich lang rechteckig, hinter den Schultern sehr schwach gerundet-erweitert, wenig gewölbt, schwach glänzend; Unterseite und Fühler rötlichgelb, Oberseite gelbrot, der Halsschild an den Vorderecken und eine grosse Makel in der Mitte des Seitendaches weissgelb, durchscheinend; letztere ist innen durch den Randstreif scharf abgegrenzt, breit und verbreitert sich nächst dem Aussenrande. Fühler nur mässig lang, nicht bis zu den Hinterecken des Halsschildes reichend, mit langer, doppelt so dicker Keule, deren Glieder mehr als doppelt so dick als lang sind. Kopfplatte zwischen den Augen schmal, vor diese in gemeinsamer Rundung, aber ohne Erweiterung mässig weit vorgezogen. Halsschild gut dreimal so breit als lang, an der Seite nicht kürzer als in der Mittellinie, mit fast rechtwinkelig, aber ganz abgerundeten, umgebogenen, dann senkrecht zur Basis laufenden Seiten und rechtwinkeligen Hinterecken; Kopfausschnitt tief dreieckig; die Scheibe mit einer glatten Querschwiele zwischen zwei punktierten Eindrücken, von welchen der rückwärtige tiefer ist. Flügeldecken vorn kaum breiter als der Halsschild, vor der Mitte am breitesten, aber mit fast parallelen Seiten; die Scheibe ohne Höcker, die Schnittpunkte ragen nicht über die Kiele hinaus; die Dorsalrippe ist vollständig, ihr vorderer Ast trifft die Mittelleiste etwas weiter aussen als der rückwärtige; auch die Humeralrippe ist vollständig, an der Basis ohne Anfangskrümmung; die Apikalleiste und ihre Anhänge sind ebenfalls vollständig, die furca interna trifft die Mittelleiste weit aussen, wenig mehr innen als die Humeralrippe; alle sind sehr niedrig. Seitendach innen auf der hyalinen Makel glatt, sonst wenig dicht, aussen in Reihen punktiert. 6.5 bis 5 mm.

Das einzige Stück wurde von Herrn W. Schultze, dem ich die Art widme, auf Luzon, Provinz Ilocos Norte, Burgos, gesammelt und ist in seiner Sammlung.

niedrigere Leisten, abgekürzte, anders gerichtete furca interna, weniger aussen gelegene Haupthöcker-Stelle, näher aneinander gerückte Schnittpunkte der Dorsalrippe von *sibuyana* verschieden. 6 bis 5 mm. MINDANAO, Surigao. Philip. Journ. Sci. 28 (1925) 580 .... *H. impicta* Sp.

29 (28). Flügeldecken gelb, mit je ein bis drei schwarzen oder pechbraunen Flecken; davon stets einer auf der Haupthöcker-Stelle, die nur ganz unmerklich über die Dorsalrippe herausragt. Die Humeralrippe ist vorne gabelig gespalten, fein und dünn.

30 (31). Flügeldecken nur je mit einem schwarzen Fleck; er steht mit seiner Mittellinie auf der Pontalleiste und reicht beiderseits noch über die Längsrippen hinaus. In Umriss und Skulptur der *sexsignata* sehr ähnlich, mit schräger zulaufenden Seiten des Halsschildes, hinten etwas breiter abgestutzten Flügeldecken, noch schwächerem Kiel des Basalhöckers. Die Stelle des Haupthöckers ist sehr niedrig und ragt über die Rippenkreuzung nicht heraus. 5.5 bis 4.75 mm. MINDANAO, Surigao, Philip. Journ. Sci. 28 (1925) 586 .... *H. corpulenta* Sp.

31 (30). Flügeldecken mit je zwei oder drei dunklen Flecken.

32 (33). Auf jeder Decke sind nur zwei schwarze Flecke, einer an der Basis, innen von der scharfkantigen nach aussen gebogenen Basis des Humeralkiels, dreieckig und von der Basis des Dorsalkiels durch zwei Punktreihen getrennt, der andere quer auf der Mittelleiste und dem Haupthöcker; dieser letztere tritt über die Rippen deutlich heraus, ist also höher als bei *corpulenta* und *undulata;* auch die anderen Höcker sind zwar sehr niedrig, aber doch deutlicher als bei jenen Arten. Umriss trapezförmig, mit der grössten Breite vor der Mitte der Flügeldecken, hinten fast abgestutzt, kürzer und breiter als die folgende Art. 5.5 bis 5 mm. MINDANAO, Butuan. Philip. Journ. Sci. 28 (1925) 584.
H. delicatula Sp.

33 (32). Auf jeder Decke sind drei dunkle Flecke; der erste an der Basis, den ganzen Raum zwischen den zwei Längsrippen ausfüllend, der zweite auf der Mittelleiste, gross, quer, nach hinten bis an den Scheibenrand verlängert, so dass nur ein kleiner heller Fleck freibleibt, der dritte auf der Apikalleiste, hinten fast bis an den Scheibenrand reichend. Die Höcker treten kaum merklich über die Rippen hinaus.

Beim Typus von *undulata* sind die Flecke unscharf, braun (unausgefärbt), der Basalfleck in seiner äusseren Hälfte verloschen. Die *Hoplionota sexsignata* Wse., bei der diese Flecke tief schwarz sind, scheint mir nicht artlich verschieden. 6.5 bis 5.5 mm. MINDANAO. Wagener, Mitt. Munch. Ent. Ver. 5 (1881) 18; Spaeth, Philip. Journ. Sci. 18 (1921) 727; Syn. *sexsignata* Wse., Deutsch. Ent. Zeit. (1915) 510.
H. undulata Wagen.

34 (17). Die beiden Teile der Dorsalrippe treffen sich auf dem Haupthöcker in dem gleichen Schnittpunkt.

35 (36). Der Apikalhöcker fehlt vollständig; die Apikalleiste fehlt aussen von der Dorsalrippe; innen ist sie durch eine kurze, gegen die Naht gehende Leiste noch angedeutet; die Anhänge der Apikalleiste sind durch eine kurze Gabelung markiert. An der Stelle des Apikalhöckers, über die die Dorsalrippe ohne Höhenveränderung führt, steht auch kein schwarzer Fleck. Von den drei schwarzen Flecken steht einer an der Basis, den Raum zwischen Humeralrippe und Aussenrand ausfüllend, der zweite schwach quer, auf und um den Haupthöcker, aussen nur bis zum Schnittpunkt des Humeralkiels mit der Pontalleiste reichend, der dritte rund, hinter der Pontalleiste, je zur Hälfte auf Scheibe und Seitendach. Die Humeralrippe hat vorne keine Aussenkrümmung, die beiden vorderen Höcker der Innenseite fehlen; Umriss fasst quadratisch, breiter und kürzer als bei den folgenden, Arten, weniger gewölbt, mit viel breiterem Seitendach. 6.5 bis 5 mm. LUZON, Tayabas, Mount Banahao. Deutsch. Ent. Zeit. (1915) 509 .... *H. sexnota* Wse.

36 (35). Die Apikalleiste berührt beiderseitig die Dorsalrippe; der Apikalhöcker ist als solcher erkennbar.

37 (40). Die Humeralrippe verläuft bis zur Basis geradlinig auf dem sechsten Zwischenraum, ohne vorher nach aussen gebogen zu sein oder einen Ast zum achten zu entsenden. Seitendach hinter der Mitte mit einem roten Ast oder Fleck.

38 (39). Umriss kurz quadratisch-subtrapezoidal, kaum länger als breit, mit der grössten Breite vor der Mitte der Flügeldecken, oberseite hell braungelb; im inneren rückwärtigen Absturz des Haupthöckers ist eine grössere, in rückwärtigen, äusseren des Apikalhöckers eine ganz kleine, nur punktförmige, pechbraune Makel; hinter der Mitte des Seitendaches ist eine schmale, rötliche Querbinde bis zum Aussenrand. 5 bis 4.5 mm. BASILAN. *H. basilana* sp. nov.[3]

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[3] *Hoplionota basilana* sp. nov. Etwa vom Umriss der *taeniata* ziemlich breit quadratisch; die Flügeldecken sind an der Basis nicht breiter als der Halsschild, dann noch kurz, sehr wenig erweitert, noch vor ihrer Mitte am breitesten, hierauf schwach konvergierend und hinten breit abgestutzt verrundet. Die Fühlerspitze erreicht nicht die Hinterecken des Halsschildes, ihre Endglieder sind merklich breiter als dick. Kopfplatte vor die Augen ziemlich weit vorgezogen und schwach erweitert, an der Spitze ohne Einschnitt gerundet. Halsschild mehr als doppelt so breit als lang, mit tiefem Kopfausschnitt, fast in rechtem Winkel gerundeten, hinten zur Basis senkrecht verlaufenden Seiten; die beiden Quereindrücke der Scheibe sind flach, kaum deutlich punktiert. Auf den Flügeldecken its die Dorsalrippe zwischen den zwei ersten Höckern kurz unterbrochen, die Humeralrippe vor der Pontalleiste deutlich, vorne aber erloschen, ohne Spur einer Anfangskrümmung nach aussen; die Suturalleiste erreicht nicht die Naht, die Apikalleiste ist kräftig, ihre Anhänge sind nur rudimentär. In der Dorsalreihe sind die beiden vorderen Höcker klein, der Haupthöcker viel höher, wenig niedriger als an der Basis breit, vierkielig, mit einem gemeinsamen Schnittpunkt; der Apikalhöcker ist niedrig.

39 (38). Gerundet-eiförmig, mit der grössten Breite erst hinter der Mitte der Flügeldecken, dann in flachem Bogen gerundet. Seitendach hinter der Mitte mit einem ziemlich breiten, hellroten Querast bis an den Rand, sonst wie die Vordach des Halsschildes hellgelb, fast glasig; Halsschild und Scheibe der Flügeldecken rötlichgelb, letztere zuweilen aussen dunkler braun, die Höckerspitzen unscharf pechbraun. Der Umriss dieser dunklen Färbung entspricht annähernd den Formen der hinteren schwarzen Flecke bei *sexsignata*. Die Dorsalrippe ist zwischen den ersten zwei Höckern kaum, zwischen den zweiten und dritten tiefer eingesenkt; der Haupthöcker ist doppelt so hoch als die anderen Höcker, halb so hoch als an der Basis breit; die Suturalleiste verläuft fast quer, die Pontal ist kräftig, die Apikal und deren gut ausgebidete Anhänge sind viel niedriger. 6.5 bis 5.5 mm. LUZON, Mount Banahao. Philip. Journ. Sci. 18 (1921) 723.
H. hedysma Sp.

40 (37). Die Humeralrippe ist vorne nach aussen gebogen; zuweilen setzt sie sich auch noch auf dem sechsten Zwischenraum schwächer zur Basis fort, so dass sie gegabelt ist.

41 (42). Seitendach mit zwei breiten, scharf ausgeprägten Randästen von der gleichen Färbung oder nur wenig heller als die Scheibe; dazwischen ist eine grosse, bis an den Rand reichende und hier breitere Fenstermakel glashell, ebenso die ganze Spitze; die Scheiben des Halsschildes und der Flügeldecken sind pechschwarz, zuweilen heller braun oder braunrot; einzelne Stellen sind besonders auf dem Halsschild oft heller. Halsschild mit gelb-glasigen Vorderecken. Kurz trapezförmig, wenig länger als breit, hinter der Schulter am breitesten und dahinter schräg konvergierend. Die Dorsalrippe ist vollständig, schneidet die Mittelleiste im gleichen Schnittpunkt, nur ganz ausnahmsweise sind zwei solche knapp nebeneinander; von den vier Höckern der Dorsalreihe ist der Haupthöcker halb so hoch als unten breit, die anderen sind niedriger; die Apikalleiste und ihre Anhänge sind etwas höher als die Humeralrippe. In der Skulptur ganz gleich mit *taeniata*, aber durch die dunkle Färbung der Oberseite (die einzige Art von den Philippinen!) verschieden. 4.75 bis 4.25 bis 5 bis 4.5 mm. LUZON, Baguio, Benguet. Philip. Journ. Sci. 18 (1921) 724................ *H. benguetina* Sp.

42 (41). Seitendach ohne scharf ausgeprägte Randäste und auch ohne gut abgegrenzte, glashelle Fenstermakel. Das Seitendach ist entweder einfärbig rotgelb, oder in der Mitte zwischen zwei wie die Scheibe gefärbten, wenig dunkleren, unscharf begrenzten Randästen innen heller. Oberseite gelb bis braunrot.

43 (44). Die Höcker sind sehr niedrig; selbst der Haupthöcker ragt kaum über die Rippe hinaus. Flügeldecken tim je vier dunklen Flecken, zwei an der Basis nebeneinander, beide länglich, der eine auf der Schulterbeule, der andere auf dem Basalhöcker, einer auf der Mittelleiste quer, der vierte auf und hinter der Apikalleiste. Seitendach einfärbig. 5.25 bis 4 mm. MINDANAO, Surigao. Philip. Journ. Sci. 28 (1925) 587.
H. surigaoensis Sp.

44 (43). Die Höcker treten mehr oder weniger über die Rippe hinaus. Hinter der Apikalleiste ist kein dunkler Fleck.

45 (46). Flügeldecken mit je einem schwarzen Fleck auf der Pontalleiste. Ober- und Unterseite gelb oder rötlich, Seitendach ohne Fensterfleck und Randäste. Umriss rechteckig, die Seiten hinter den Schultern etwas erweitert, dann sehr wenig konvergierend. 5 bis 4.25 mm. LUZON, Verh. zool. bot. Ges. 57 (1907) 137.
H. bipunctata Sp.

46 (45). Flügeldecken ohne gut ausgebildete schwarze Flecke, einfärbig gelb bis rotbraun, oder die erhöhten Stellen der Rippen und Höcker unscharf dunkler, gelbbraun, bis pechbraun.

47 (50). Der Haupthöcker ist so hoch als an der Basis breit, scharf gewinkelt. Seitendach ohne Randäste.

48 (49) Breiter, kürzer, mit kürzerem Halsschild, vorne breiterem, nach hinten mehr verengtem Seitendach. Oberseite hell rostrot, der Halsschild beiderseits des Kopfes, das Seitendach innen vor der Brücke und an der Spitze heller glasig. 5.5 bis 5.25 mm. NEGROS, Cuernos Mountains. Philip. Journ. Sci. 28 (1925) 579.
H. demutata Sp.

49 (48). Schlanker und länger, mit längerem Halsschild und schmälerem Seitendach. Oberseite schmutzig gelbbraun, Halsschild und Seitendach heller gelbbraun, letzteres innen vor der Mitte heller. 5.5 bis 5 mm. MINDANAO, Butuan. Philip. Journ. Sci. 28 (1925) 577 .... *H. butuana* Sp.

50 (47). Der Haupthöcker ist nur halb so hoch als an der Basis breit. Zeichnung und Form nicht ganz konstant; der Umriss ist meist kurz trapezförmig, mit der grössten Breite gleich hinter den Schultern, die Seiten von hier nach hinten schräg konvergierend, die Spitze abgestutzt verrundet; seltener liegt die grösste Breite erst vor der Mitte und die Verengung nach rückwärts ist weniger auffällig. Die Färbung der Oberseite ist gelbbraun bis rotbraun, meist sind einzelne Höckerstellen dunkler braun; das Seitendach hat fast immer eine Andeutung von zwei gesättigter gefärbten Randästen, obwohl besonders der vordere oft so schwach ist, dass er kaum bemerkt wird. Bei der ab. *biramosa* Wagener, Mitt. Münch. Ent. Ver. 5 (1881) 19, sind die beiden Randäste merklich dunkler als das übrige Seitendach und zwischen ihnen ist eine fast glashelle Fenstermakel; bei dem Typus dieser Form sind auch alle Höckerspitzen, die Pontalleiste und ein Wisch vorn zwischen Scheibenrand und Humeralrippe, der bis zur Pontalleiste reicht, hell pechbraun. Alle Höcker sind bei dieser Art niedrig, die ersten zwei der Innenreihe wellenförmig; der Haupthöcker ist vierkantig. Die häufigste und am meisten variierende Art auf den Philippinen. 4.25 bis 3.75 bis 5.75 bis 5 mm. LUZON; SIBUYAN; BALABAC.
H. taeniata F.

ILLUSTRATION

TEXT FIGUR 1. Skulptur der Flügeldecken der *Hoplionota.*

BERICHT ÜBER "EINE NEUE HYDROBIIDÆ VON DEN PHILIPPINEN"

Von BERNHARD RENSCH
Zoologisches Museum der Universität Berlin

Die von Herrn Dr. J. Begnaert erfolgte Bestimmung der von Dr. Tubangui gesammelten Hydrobiide als *Blanfordia quadrasi*[1] veranlasste mich, die mir übersandten und als *Oncomelania hydrobiopsis* beschriebenen Stücke (letztes Heft des Philippine Journal of Science) norh einmal zu überprüfen. Leider lag mir im Berliner Museum kein Material von dieser Art vor, sodass ich mich ursprünglich auf den Vergleich mit der ohne Abbildung publizierten lateinischen Diagnose O. von Moellendorffs beschränken musste. Danach schien aber die Art micht in Frage zu kommen, da sie als "plicato-striata" beschrieben wird, wahrend die mir vorliegenden Stücke glatt aussahen.

Ich wändte mich nun an Herrn Dr. Haas, der mir freundlicherweise einen Paratyp von *quadrasi* aus dem Besitz des Senckenberg Museums eintauschte. Dieses Stück stimmt in allen Merkmalen mit den mir übersandten Schalen überein, ist aber in der Tat deutlicher "plicato-striata." Da jedoch das Periostracum bei dem Paratyp fehlt, so ist der Strukturunterschied wohl auf diese Weise zu erklären. *Oncomelania hydrobiopsis* moechte ich deshalb, nun keine Verwirrung zu stiften, hiermit wieder einziehen, selbst für den Fall, dass spaeterhin eine entsprechende Differenzierung als geographische Rasse moeglich waere. Moege wenigstens die erstmalige Beschseibung und Abbildung von Radula und Deckel zur Klaerung beitragen.

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[1] Philip. Journ. Sci. 49 (1932) 298.

A MARINE CRANE FLY, LIMONIA (DICRANOMYIA) TRIFILAMENTOSA, OF THE PACIFIC COAST OF JAPAN, WITH SPECIAL REFERENCE TO THE ECOLOGY AND THE MORPHOLOGY OF ITS IMMATURE STAGES.[1]

By MASAAKI TOKUNAGA

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THREE PLATES AND TWO TEXT FIGURES

INTRODUCTION

Only the following marine crane flies are recorded in the whole world in spite of the amazing number of crane-fly species of fresh-water habitats:

- *Trimicra (Psiloconopa) marina* Pierre. Pierre, 1924, Ambleteuse, North France.
- *Limonia (Geranomyia) bezzii* Alexander and Leonard. Seurat, 1924, Tunis, North Africa.
- *Limonia (Dicranomyia) signipennis* Coquillett. Saunders, 1928, Newcastle Island, Canada.
- *Limonia (Limonia?) halophila* Alexander. Alexander, 1929, South Chile and Patagonia.
- *Limonia (Geranomyia) unicolor* Haliday. Saunders, 1930, North Wales, England.
- *Limonia (Dicranomyia) monostromia* Tokunaga. Tokunaga, 1930, Seto, Japan.

In addition to the above species Saunders reported that an undescribed marine crane fly had been collected by Edwards on the coast of Chile in 1927 and Prof. J. S. Rogers kindly informed the author that another one, *Limonia (Dicranomyia) floridana* Osten Sacken, was collected from the *Juncus* marshes of brackish tidal flats of Florida, United States. From Japan three marine crane flies have been collected at Seto, Wakayama Prefecture, including *L. (D.) monostromia* which was reported by the present author in 1930. The other two undetermined species are newly named by Alexander as *L.* (*D.*) *trifilamentosa* and *L.* (*Idioglochina*) *tokunagai,* respectively. Another marine crane fly[2] was obtained at Seto in the summer of 1931, when a few imagines of this species were bred out in the laboratory from larvæ collected from various algæ growing between the tide marks. In the summer of 1931 the author collected again various stages of *L.* (*D.*) *trifilamentosa* Alexander at Seto and certain ecological points of this species were observed there with the help of Mr. N. Omori.

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[1] Contribution from the entomological laboratory, Kyoto Imperial University, No. 24.

In the present paper the author reports on the larval and pupal stages of *Limonia* (*Dicranomyia*) *trifilamentosa* Alexander based on ecological observations made chiefly in 1931, supplementing those of preceding seasons since 1926, together with morphological studies comparing this species with several other marine crane flies.

These studies were mainly undertaken at the Seto Marine Biological Station of the Kyoto Imperial University under the direction of Prof. Hachiro Yuasa, to whom I am grateful for the help that made these studies possible. I wish to thank Prof. Charles P. Alexander and Dr. F. W. Edwards for suggestions on the marine crane flies. I am deeply indebted to Prof. K. Okada for the use of equipment at Seto. I wish to thank Mr. N. Omori, an advanced student of our laboratory, for his assistance, especially his valuable observations on emergence.

MORPHOLOGY OF THE LARVA

GENERAL REMARKS

This marine crane-fly larva is comparatively small, slender, and cylindrical in general appearance, being 9 to 10 millimeters in length in the spring form and 8 to 8.6 millimeters in the summer form in its full-grown stage. The color of the living larva is semihyaline and yellowish or brownish green, according to the algal color of the habitat. The creeping welts are brown, and arranged six on the dorsal side and six on the ventral side. Thus, the larva is not highly different in general appearance from other marine crane-fly larvæ in respect to its coloration and creeping welts; but this larva bears characteristic structures on the head, the mouth parts, and the respiratory anal disk. The mandibles greatly resemble those of *L.* (*D.*) *monostromia*, excepting the undentated mola and the plumated brustia of the present species. The mentum is similar to that of *L.* (*D.*) *signipennis* in the number of the teeth and the relative size of the small median tooth, but the anterior outline of *L.* (*D.*) *signipennis* is more convex than that of the present larva. In this larva the postclypeus is well chitinized and distinct and the preclypeus is narrow and transverse; whereas, in *L.* (*D.*) *signipennis* and *L.* (*D.*) *monostromia*, the postclypeus is represented by a membranous area, while in *L.* (*Geranomyia*) *unicolor* both the post- and preclypeus are completely membranous. The hypopharynx of this larva bears six teeth. The salivia also has six large teeth and is provided with three pairs of small lateral teeth. These structures of this species closely resemble those of *L.* (*G.*) *unicolor*. This species, *L.* (*G.*) *bezzii*, and *L.* (*D.*) *monostromia* have the same number of teeth on the hypopharynx, but they differ from each other in that of the salivia. The salivia of *L. monostromia* is flanked with only one pair of small teeth, instead of three pairs, and that of *L. bezzii* is flanked with two pairs of small teeth and in addition has a large unpaired tooth. When the present larva is compared with another marine fly, *L.* (*D.*) *signipennis*, the following distinct differences may be pointed out: On the hypopharynx the latter species is provided with one median tooth beside the six teeth and on the salivia with only four large teeth and one pair of small teeth. In the structure of the maxillæ *L.* (*D.*) *trifilamentosa* has no conspicuous specific characteristics and resembles the other marine species in its general structure. The antennæ of this species are comparatively long; those of *L.* (*G.*) *unicolor* and *L.* (*D.*) *signipennis* are short. Besides the above general appearance the structure of the apical sensory receptors of the antenna is characteristic in each species. The spiracular anal disk of this larva is similar in outline to that of *L.* (*D.*) *signipennis*, but the brown quadrangular or oval spots, which are found on the inner side of the four anal lobes of many crane-fly larvæ, are wanting in the present species.

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[2] This species is yellowish, small, about 13 millimeters in wing expanse, lacks both the intermedian crossvein and the proximal deflected part of vein M_3; thus the median cell is wanting. This fly probably belongs to the subgenus *Dicranomyia.*

HEAD CAPSULE

The head capsule is compact, highly chitinized, and incompletely retractile. The main part of the head capsule is divisible into the dorsal median sclerite, the front, and the paired lateral sclerites, the verticis, by the deep ventral median and the paired, shallow, lateral incisions. The front is shield-shaped, being closely fused with the internal lateral sclerites on its lateral and caudal margins, and on its cephalolateral corners four sensory receptors are found respectively. The vertex is large, mussel-form, and provided with one seta and two large sensory pores on its caudal part. There is one pair of large highly chitinized areas on the head capsule cephalad of the deep lateral incisions.

MOUTH PARTS

The labium is represented only by the dentated mentum, completely losing its palpi and membranous structures. The mentum (*m*) is broad, with seven distinct teeth and one pair of very tiny lateral teeth. The teeth of the mentum decrease in size laterad, excepting the unpaired median tooth, which is small and half as large as the adjacent largest teeth. On the ventral surface of the lateral parts of the mentum there are shallow depressions for the articulation of the subcardines (*sa*). The submentum is also highly chitinized, being divided by a Y-shaped pale stripe from the mentum, extended caudad along the margin of the ventral incision and closely fused with the ventral margins of the verticis. There is a pair of small, chitinized, hook-shaped projections on the mesal margins of the arms of the submentum (Plate 2, fig. 12).

The labral projection is membranous and consists of two large unpaired sclerites on its dorsum and a small paired sclerite on its lateroventer. On the lateral membrane of the clypeal region there are one pair of stiff setæ on the distal part, one pair of long, slender setæ on the proximal parts, and beside these setæ a pair of sensory pegs. The caudal subpentagonal sclerite is the postclypeus (*po*), which is smooth, setæ being wanting. The cephalic, transverse, U-shaped sclerite is the preclypeus (*pe*), which bears two sensory pores and one strong seta on each end of the cephalolateral arms. The distal membranous area, the labrum (*l*), is densely fringed with very strong setæ; the lateral margins of its distomedian area are covered with minute setæ, and its caudolateral corners bear a pair of sensory discs, each of which is furnished with one large and two small blade-shaped setæ and two very minute sensory pegs. Besides these sensory discs the labrum bears two pairs of sensory pegs and one pair of blade-shaped setæ near the sensory discs. The ventral side of the labrum, the epipharynx, is furnished with a pair of tufts of hairs and a pair of small chitinized sclerites, the tormæ (*tm*) (Plate 2, fig. 11).

The mandible is firmly articulated to the chitinized mandibularia, which is not demarked by a distinct suture from the head capsule, by the large postartis (*pa*) and the triangular preartis (*pr*) and provided with a long extensotendon (*et*), which is attached to the end of the scrobal arm, and a very large retractotendon (*rt*) attached to the mesal concave margin of the mandible. There are four proxadentes (*pd*), of which the apical tooth is sharp and extends distad; the other cutting teeth are more or less broad and extend mesad. Besides these teeth there are two distadentes (*dd*), which are located on the inner side of the mandible and unequal in size, the distal being larger than the proximal tooth. The mola (*ml*) is not dentated and provided with the plumated brustia (*b*) on its proximal end. No hairs are found on the mandible, except the above brustia and a sensory peg located on the base of the scrobal arm (Plate 2, fig. 13).

The maxilla is connected with the vertex by the broad maxacoria (*nc*) and with the mentum by the mesal end of the subcardo (*sa*) and divided into the lateral and the mesal lobes. The lateral lobe consists of a large chitinized plate and membranous area on its proximal region and provided with a blunt, membranous, mesal projection and a short, chitinized, cylindrical projection on its distal region. The chitinized plate, the stipes (*s*), covers most of the area of the external and the ventroental surfaces of the proximal region of this lobe and is provided with two sensory pegs on its laterodistal corner. The broad membranous area of the proximal region of this lobe is provided with a long sensory hair on the distal part of the external side and a longitudinal row of slender hairs on its inner side. Of the two distal projections the inner membranous one is the galea (*gl*), which is fringed with setæ on the lateral and mesal margins but not on the apical margin and its external and inner sides are without setæ and sensory organs. The external projection is the maxillary palpus (*mp*), which is not segmented, is crowned with three tiny sensory pegs on its membranous tip, and is articulated to the ectodistal part of the stipes by the intermediation of a narrow membrane. This narrow membrane is the palpifer (*pf*) and bears a long sensory peg. The mesal lobe is very broad and consists of two chitinized plates on its external membranous surface, a uniform membranous area on its inner side, and a large, distal, membranous projection. Of these two plates the distal triangular one is the alacardo (*al*), which is broadly expanded onto the external surface of the distal projection and devoid of setæ and sensory receptors. The other obliquely long plate is the subcardo (*sa*), which bounds the proximal part of this mesal lobe and is provided with two long setæ on its lateral end. The broad, distal, membranous projection, the lacinia (*la*), is fringed with large strong setæ on its mesal margin and with slender setæ on the distal and lateral margins and is provided with four large sensory pegs on its ectodistal side. The inner side of the lacinia is covered with minute spinules on its distomesal region (distad of the chain line in the figure). Beside these structures there is a small chitinized plate on the external side of the lacinia along the lateral margin of the alacardo (Plate 2, fig. 14).

The hypopharyngeal region consists of two sharply dentated superimposed plates, forming between them the salivary cavity. At the center, in the caudal part of this cavity, the common salivary duct (*sd*) opens. The anterior plate, the hypopharynx proper (*hx*), is provided with six subequal teeth. The posterior plate, the salivia (*sl*), has twelve teeth, of which the median four are largest and subequal, the next lateral tooth on each side is slightly smaller, and the remaining three teeth on each side are smallest and needlelike. The two posterior arms of the salivia are extended caudad, supporting the lateroventral sides of the salivary cavity, and each is provided with a tendon at its caudal tip. The ventral wall (*el*) of the salivary cavity, between the two arms of the salivia, is setigerous with stiff needlelike bristles. There are three pairs of sensory receptors; two pairs on the cephalic margin of this setigerous membrane and one pair on the proximodorsal sides of the salivial arms. The lateral side of the hypopharyngeal region is supported by the rhombic sclerites, the pharyngea-lingula (*pl*), which bears four tendons, one on each corner. Of these tendons the smallest one connects with the hypopharynx; the dorsocephalic is the pharyngeatendon (*pt*), the dorsocaudal is the liguatendon (*ld*), and the ventrocaudal is the paralinguatendon (*pi*). The small membranous area between the hypopharynx and the pharyngea-lingula bears soft marginal hairs (Plate 2, fig. 15).

ANTENNA

The antenna (*a*) is elongate cylindrical and fitted on the antacoria (*ac*), which is located distad of the thickly chinitized antennaria. On the proximal part of the antenna there is a sensory pore and on the distal membranous end are a mushroom-shaped sensory organ and two small and one large trichoid sensory organs (Plate 2, fig. 9).

THORAX AND ABDOMEN

On the thoracic segments the dorsal creeping welts are completely wanting and the ventral creeping welts are weakly developed on the two posterior segments. The prothoracic segment is subdivided into three annulets, and the cephalic margin of the anterior annulet is fringed with minute spinules; the two posterior thoracic segments are each subdivided into two annulets, and the vestigial creeping welts are found only on the ventral side of these anterior annulets. The abdomen is divided into nine segments; the first abdominal segment is similar in structure to each of the posterior two thoracic segments, excepting in the chætotaxy; the following six abdominal segments are subequal to each other in number of annulets, in arrangement of setæ, and in structure of dorsal and ventral creeping welts, which are found on the anterior annulets. The seventh segment is slightly different from the preceding segments in the arrangement of minute spinules on the posterior margin of its posterior annulet. The small penultimate segment is subdivided into two annulets and both the dorsal and ventral creeping welts are completely wanting. The extreme segment is not subdivided into distinct annulets and at its caudal end is provided with four lobes, which form the spiracular anal disk. The anus is situated on the ventral side of the ultimate segment near the penultimate segment (Plate 1, fig. 8).

The spiracular disk consists of four distinct lobes and its entire margin is fringed with a row of soft marginal hairs. The small dorsal lobe at its distal part is provided with a seta on its dorsal side and a sensory hair among the marginal hairs. The large ventral lobe at its distal part is provided with four setæ accompanied by a minute sensory receptor on its outer side and two large and two small sensory hairs on its inner side. On the inner side of the bases of the paired dorsal lobes there are two ovate spiracles (Plate 2, fig. 10). The setæ on the body, excepting on the extreme segment, are all slender and tubaculated basally, and sometimes, especially common on the thoracic segments, two or three hairs are situated together on a common membranous tubercle. The small sensory hairs are found in company with the tubaculate hairs. The distribution of the setæ and the sensory hairs is shown in text fig. 1.

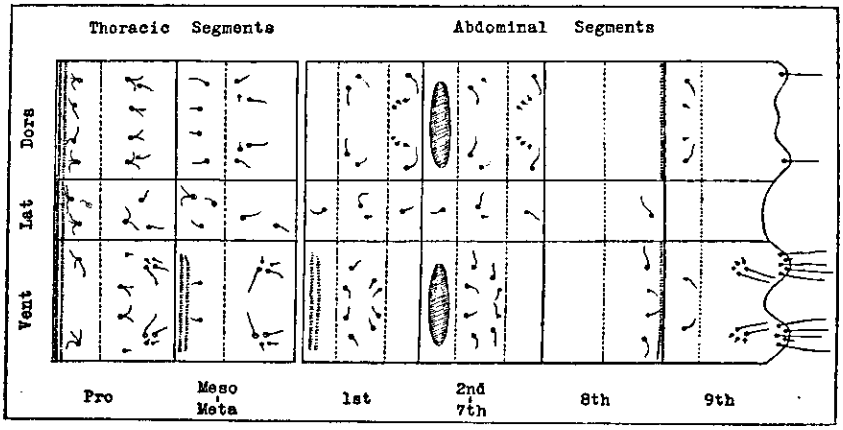

FIG. 1. Arrangement of hairs on the thoracic and abdominal segments of the larva of *Limonia trifilamentosa* Alexander.

MORPHOLOGY OF THE PUPA

GENERAL REMARKS

The pupæ of this species are different in size according to sex and season. The male pupa is smaller than the female and the spring form is larger than the summer and autumn form. They measure 8 to 9.2 millimeters in length in the female and 7 to 7.8 millimeters in the male of the spring form; in the summer and autumn forms they are 6.2 to 7 millimeters and 5.2 to 5.8 millimeters, respectively. The body is slightly yellowish white and semihyaline, excepting the chitinized brown parts such as the respiratory organs, the head parts, the thorax, the wing sheaths, the leg sheaths, and the genital sheaths.

The pupal form of this species is very different from the known pupæ of other marine crane flies in the structure of the thoracic respiratory horns and the genital sheaths and in the arrangement of the creeping welts. The trilobated respiratory organ is unknown in the other marine crane flies. There are five creeping welts on the dorsal side and four on the ventral side. The arrangement of the creeping welts on the dorsal side greatly resembles that of *L.* (*G.*) *unicolor* and *bezzii*, but is different from any of the other marine *Limonia* (*Dicrano-*

myia) species in which the creeping welts are less than five in number, being usually four. On the ventral side the creeping welts are at most three, as in *L.* (*G.*) *unicolor* and *bezzii*, and usually two in other *Limonia* (*Dicranomyia*) species. The genital sheath of this crane fly is also characteristic in the structure of the papilliform projection of the dorsal valve and in the possession of the ventrally curved, hooklike projection of the ventral valve. In all other marine crane-fly pupæ the dorsal projections are curved dorsally and the ventral projections of the ventral valves are wanting.

HEAD

The head part is small, flattened, subhexagonal, and wrinkled on its surface, occupying the cephaloventral side of the body and devoid of conspicuous hairs or tubercles. The main part consists of the broad paired verticis and the small triangular front which are divided by the epicranial suture from each other. The vertex (*v*) is devoid of the crest and split along the thickened epicranial stem at emergence. The caudal margin of the linavertex and the gena is projected laterocaudad and overlies the knee joint of the foreleg sheath and the tip of the maxillary palpal sheath (*mp*). The triangular front (*f*) is indistinctly divided by the wrinkly sutures, the inverted V-shaped epicranial arms, from the vertex and by the transversal frontolabral suture from the labral sheath (*ls*) and provided with three pairs of sensory receptors on its lateral margins. The antennal sheath (*as*) is not provided with spines and hairs, arises above the eye, bends caudad along the lateral margin of the vertex and the outer side of the knee joints of the leg sheaths, and ends at the root of the wing sheath. The compound eye (*ce*) is comparatively larger in the male than in the female and located on the lateral side of the vertex. The labral sheath (*ls*) is small, inverted trapezoid in shape, and situated on the anterior margin of the front. The labial sheaths (*is*) are contiguous and narrow along the anterior margin of the labral sheath overlying the bases of the foreleg sheaths. The sheath of the maxillary palpus (*mp*) is V-shaped, located on the margin of the gena, and overlies the distal end of the femur of the foreleg (Plate 1, figs. 1 and 2).

THORAX AND ABDOMEN

The thorax is well chitinized and consists of a small prothorax, a large mesothorax, and a narrow metathorax. The prothorax bears a pair of large, characteristic, trilobated, respiratory, horns. The three lobes of this horn are subequal in length and about one-third or one-fourth as long as the body length, but occasionally the length of the lobes is reduced to about one-fifth. The mesothorax is gibbous and highly thickened along its mid-dorsal line. This dorsomedian or mid-dorsal suture is split in the process of emergence. The wing sheath is small, arises at the caudolateral part of the mesothorax, is extended caudoventrad, overlying the lateral half of the sternal region of the metathorax, the first and the second abdominal segments, and ends on the posterior annulet of the second abdominal segment. The leg sheaths are parallel to each other on the ventral side and end on one level on the posterior annulet of the third abdominal segment. The proximal parts, proximad of the tibia, of the middle and the hind leg sheaths are covered over each by the preceding leg sheaths, respectively, and furthermore the tibia and the proximal part of the tarsus of the hind leg sheath are also covered over by the wing sheath. The halter sheath is pale and hidden beneath the wing sheath.

The abdomen consists of eight segments and a genital sheath. The anterior seven segments are provided with rudimental spiracles on their lateral sides, and each is subdivided into three annulets. The penultimate segment is very small and narrow, not subdivided into annulets, and its spiracles are close together on the dorsal side. The dorsal creeping welts are arranged on the anterior annulets of the third to the seventh segment and the ventral creeping welts on the anterior annulets of the fourth to the seventh segment (Plate 1, fig. 1). The structures of the creeping welts are similar to those of the larva, spindle-shaped, and are provided with many chitinized claws, as shown in fig. 7. These claws on the peripheral part are smaller than on the middle part of the welt. The structure of the setæ on the body is similar to that of the larva and their arrangement is shown in text fig. 2.

The genital sheaths of both sexes are highly chitinized, provided with four pairs of setæ on the proximal part; two pairs are on the lateral sides, and the remaining two pairs are on the dorsal side and with a pair of very thickly chitinized, hooklike projections, which curve ventrad on the posterior end. On the female the tip of the genital sheath consists of the incompletely divided ventral valves (*sv*) and the paired dorsal valves (*dv*). The ventral valves are furnished with a pair of strong hooklike projections on the distal part and a pair of blunt lateral projec-

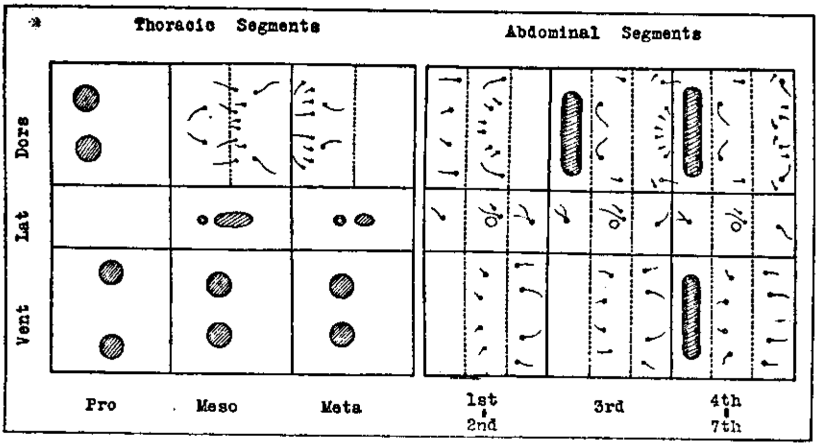

FIG. 2. Arrangement of hairs on the thoracic and abdominal segments of the pupa of *Limonia trifilamentosa* Alexander.

tions on the proximal part. The dorsal valves are provided on the dorsal side with small papilliform projections (Plate 1, fig. 4), each of which bears a minute sensory peg and two slender hairs on the tip and a blunt projection (Plate 1, fig. 3) on the proximal part.

On the male genital sheath the ventral valves extend far beyond the dorsal ones; the hooklike projections are located on the tip of the ventral valves and more sharply curved ventrad, while in the female these are located slightly cephalad of the tip; the lateral projections of the ventral valves are larger than those of the female. The dorsal valves are broader than those of the female and the papilliform projections are located on the proximal part of the genital sheath. This papilliform projection of the male (Plate 1, fig. 6) is more pointed and broader than that of the female and provided with four hairs on its distal part. Besides the above structures there is a pair of deep depressions on the lateroproximal part of the genital sheath of the female and on the dorsoproximal part of the genital sheath of the male (Plate 1, fig. 5).

ECOLOGICAL REMARKS

The adults of this crane fly are found on the seashore throughout the spring and summer seasons at Seto after the first emergence the beginning of April. Late comers may be found in the early autumn, for several imagines were collected in the middle of September. This indicates that this fly repeats its generation more than once a year; and there may be more than two generations, although this point has not been determined. The immature forms of this crane fly are found on different species of algæ in different seasons, showing that the breeding algal bed of this crane fly is alternately changed according to the seasonal succession of the algal flora of the shore. Through the winter and early spring the habitat of the crane fly is confined to the sea algæ *Ulva pertusa, Ulva conglobata,* and *Monostroma* sp., which are found on the horizontal level of the tidal zone inhabited by certain Mollusca, *Modiolus atratus* Lischke, *Septifer crassus* Dunier, etc. In the later spring and summer seasons these algæ all disappear and the habitat of the crane fly is then other littoral algæ, such as *Myelophycus caespitosus* and *Boodlea* sp.

Generally, both the pupal and the larval nest cases are built under individual plants of these algæ, but when the colonies of this fly are established on the algal matting where the individual algæ are not separated the nest cases are built on the hard rock surface, underneath the entangled thalli of algæ. These nest cases of this species are similar to those of *L.* (*D.*) *monostromia* but are more loosely built than the latter.

Although the breeding places of this crane fly are comparatively limited to several littoral algæ, the feeding habit of the larva is not strictly oligophagous but is sapropolyphagous. The larval stomach contents reveal its wide food habit. The food consists of sedentary diatoms and dead algal filaments mingled with a small quantity of sand particles in addition to fragments of these living algæ which are used by the immature forms for their shelters.

The habitat of this crane fly is regularly submerged under the water in accordance with the tidal rhythm. This rhythmical change of the tidal condition has many effects on the various habits of the crane fly on some of which observations were made to some extent. The stomachs of the larvæ collected immediately after the recession of the tide are found generally empty and only in a very few cases they contained a small quantity of digested food in the hind intestine. While those larvæ collected before the flood tide are without exception filled with the food items throughout the entire midintestine. This indicates rather plainly that the larvæ feed during the ebb tide and refrain from feeding during the flood tide.

The activity of the larva is also affected by the tidal condition. In the natural condition the larvæ remain quietly in their nests at flood tide. In the laboratory a similar condition was observed by filling the larval quarters deep with sea water at any time of the day. Although the larvæ normally remain in their nests at ebb tide, they sometimes creep out of their nests and may be found moving about on the surface of the algal matting.

Another conspicuous habit that may be related to the tidal rhythm is that of emergence. The emergence of the adult takes place only in the ebb-tide condition. On a suitable algal matting many pupal exuviæ may be found at ebb tide. The emergence commences immediately after the tide has receded and lasts to the next flood tide, the great majority of imagines emerging during about one to three hours after the breeding bed becomes exposed to the air. Before emergence the mature pupæ remain quietly jutting out their respiratory horns from the larval nest, which now serves equally well as the pupal case. When ready to emerge the pupæ wriggle out from their nests and expose their thoracic parts in the air and then remain quiet until the middorsal sutures are split. This process takes one to twenty minutes, varying much in different individuals. After the middorsal suture is split, the emerging process is completed within five to ten minutes, and the freshly emerged milky-colored fly takes to the wing without awaiting the hardening of the integument and the wings. The emerging process was observed in the field and the following data were obtained:

Process of emergence.	No. 1, August 13, 11 a. m.		No. 2, August 26, 10. a. m.	
	m	*s*	*m*	*s*
Pupal thorax wriggled out from algæ	18	00	7	00
Mild-dorsal suture split	40	00	8	30
Thorax of imago began to appear	41	00	8	40
Thorax completely emerged, abdomen and wings began to appear	42	00	8	50
Wing completely emerged	42	40	9	00
Forelegs completely pulled out	42	50	0	00
Body extended in maximum length jutting up perpendicularly	42	52	9	30
Wing expanded	42	53	10	00
Body bent ventrad supported with forelegs	42	55	10	06
Middle and hind legs and abdomen completely emerged	43	10	10	30
Wing folded over the back	43	12	10	31
Quietly resting	43	12	11	00
Walk slowly forward	43	20	0	00
Abdomen contracted to the length of the wings	46	00	13	00
Taken on the wing	50	00	13	30

In the process of emergence the maximum length of the body measured 9.5 (8 to 10) millimeters; the matured normal fly is about 4 millimeters in length. The completely emerged fresh fly becomes normal in color and size within thirty minutes.

The imagines are nocturnal in habit, hence the mature adults are not found at the seashore actively flying after their food, nor for oviposition, mating, or swarming in the daytime, but quietly resting on the vertical or overhanging sides of rocks or in the rock caves along the shore. Occasionally, the adults are collected in the beating net from the bush along the seashore in the daytime. The resting position of this fly closely resembles that of *L.* (*D.*) *monostromia;* that is, the body is closely applied to the substratum with the six legs outstretched like those of a spider. In the twilight of the evening the imagines actively take to the wing from their diurnal haunts and fly about over the rocky shore throughout the night for mating and oviposition.

The mature egg is oval, 248.5 μ in length and 208.1 μ in diameter, and brown with the pointed pole black. The surface of the egg is finely granulated, and at the center of the black-pointed pole is the micropyle, the peripheral area of which is very finely granulated. The female fly contains about 120 mature eggs; most of these eggs are laid during her life, as the spent females are usually devoid of eggs. The eggs are placed singly in the algæ or in the small crevices of the rocks by a rapid up-and-down motion of the whole body produced by the flection of the legs. The presence or absence of algæ does not condition the deposition of the eggs since they are often laid on a completely bare rock. They are never laid on a dry surface whether it be algal or rock.

This crane fly, in all the stages, is subject to attack by many natural enemies, some of which are common with *L.* (*D.*) *monostromia,* for these two crane flies are similar in habitat in the spring season. These common natural enemies are a bat, *Miniopterus schreibersii japoniæ* Thomas, which attacks the adults on the wing; a bird, *Actitis hypoleucos* (Linnæus), which attacks the immature forms; a littoral red mite, *Molgus littoralis* Linnæus, which attacks the adults just in process of emergence; some robber flies, *Antipalus* sp., *Oligopogon* sp., and one other fly, which attack the adults on the wing, and a dragon fly, *Orthetrum japonicum* Uhler, which also catches the adults. Besides the above enemies a spider and some predacious insects, such as a littoral jumping spider, a dragon fly, a tiger beetle, and an anthomyid fly, also attack this crane fly in various stages.

The littoral jumping spider probably belongs to the genus *Salticus;* it usually wanders on the seashore at ebb tide and mainly attacks the imagines in the process of emergence and occasionally also attacks the larvæ creeping on the algæ. The dragon fly *Pantala flavescens* Fabricius, the imagines of which swarm on the seashore in large number in August and September, catches the imagines of this crane fly on the wing. The tiger beetle *Cicindela nivicincta* Chevrolat var. *inspecularis* Horn, which walks on and flies low over the rocks at ebb tide, devours the immature forms of this crane fly and the adults just in process of emergence. The larva of the littoral anthomyid fly, the imago of which mainly attacks the small marine chironomid flies, also attacks the larvæ of this crane fly.

SUMMARY

1. The external anatomy of the larval and pupal forms of a marine crane fly, *Limonia* (*Dicranomyia*) *trifilamentosa* Alexander, is described.

2. The immature forms of this species are distinguished from those of the other known marine crane flies by the following conspicuous characteristics: (*a*) In the larval stage the labrum consists of the chitinized preclypeus and postclypeus; the mentum and hypopharyngeal sclerites are provided with the teeth characteristic in number and size and the respiratory disk is also specific in structure. (*b*) In the pupal stage the characteristic structures are the trilobate paired respiratory horns, the chitinized genital sheaths which are provided with the ventrally curved hooks on the ventral valves, and the creeping welts.

3. The imagines of this crane fly are found from spring to autumn and the generation may be repeated more than once, probably twice or more. The breeding place changes according to the seasonal algal succession. The feeding habit of the larva is neither monophagous nor oligophagous but sapropolyphagous and it seems to take food practically exclusively at the ebb tide. The emergence of the imago is limited to the ebb-tidal condition, and after the middorsal suture is split the process is completed in about ten minutes. The imago is nocturnal in habit. The female contains about 120 well-developed eggs, nearly all of which are laid singly during her life.

4. This crane fly is attacked by various natural enemies in its various stages; namely, the larval stage by a snipe, a littoral jumping spider, a tiger beetle, and an anthomyid larva; the imago

in the process of emergence by a littoral red mite and a littoral jumping spider; and the imago on the wing by a bat, two species of dragon flies, and three species of robber flies.

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ILLUSTRATIONS

LIMONIA (DICRANOMYIA) TRIFILAMENTOSA ALEXANDER

PLATE 1. PUPA AND LARVA

FIG. 1. Female pupa, lateral aspect.
2. Head of the female pupa, frontal aspect.
3. Genital sheath of the female pupa, lateral aspect.
4. Dorsal projection of the genital sheath of the female pupa, dorsal aspect.
5. Genital sheath of the male pupa, lateral aspect.
6. Dorsal projection of the genital sheath of the male pupa, dorsal aspect.
7. Various claws of the creeping welt of the pupa.
8. Full-grown larva, lateral aspect.

as, antennal sheath.
ce, compound eye.
dv, dorsal valve.
f, front.
is, labial sheath.
ls, labral sheath.
mp, sheath of the maxillary palpus.
sv, ventral valve.
v, vertex.

PLATE 2. LARVA

FIG. 9. Antenna, lateral aspect.
10. Respiratory anal disk, caudal aspect.
11. Labrum, dorsal aspect.
12. Mentum and its accessory parts, ventral aspect.
13. Mandible, mesal aspect.
14. Maxilla, lateral aspect.
15. Hypopharyngeal region, ventral aspect.

a, antenna.
ac, antacoria.
al, alacardo.
b, brustia.
dd, distadentis.
el, oscula.
et, extensotendon.
gl, galea.
hx, hypopharynx proper.
l, labrum.
la, lacinia.
ld, linguatendon.
m, mentum.
ml, mola.
nc, maxacoria.
pa, postartis.
pd, proxadentis.
pe, preclypeus.
pf, palpifer.
pi, paralinguatendon.
pl, pharyngea-lingula.
po, postclypeus.
pr, preartis.
pt, pharyngeatendon.
rt, retractotendon.
s, stipes.
sa, subcardo.
sd, salivary duct.
sl, salivia.
tm, torma.
v, vertex.

PLATE 3. HABITAT

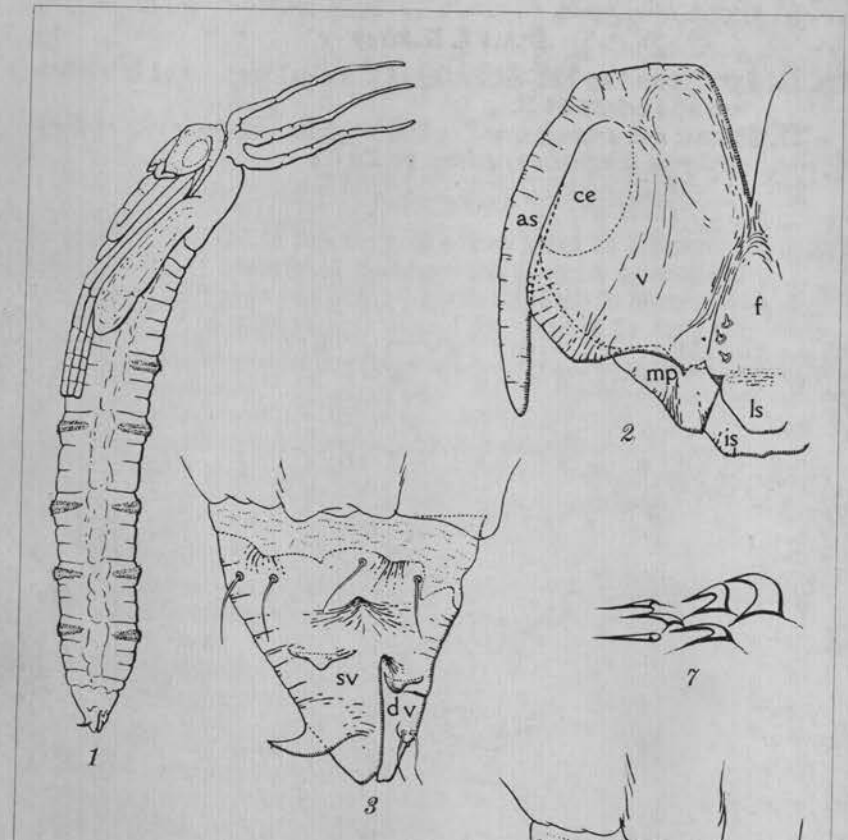
FIG. 16. Spring breeding bed, consisting of the algal matting of *Monostroma* sp.; colony at X.

17. Summer and autumn breeding bed, consisting of the colony of *Myelophycus caespitosus;* colony at X.

TEXT FIGURES

FIG. 1. Arrangement of hairs on the thoracic and abdominal segments of the larva of *Limonia trifilamentosa* Alexander.

2. Arrangement of the hairs on the thoracic and abdominal segments of the pupa of *Limonia trifilamentosa* Alexander.



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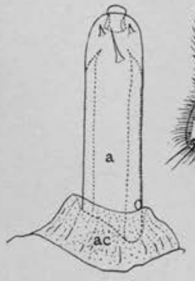

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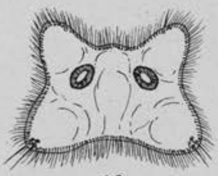

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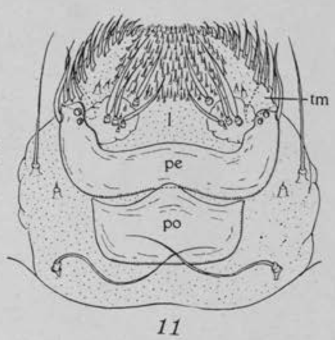

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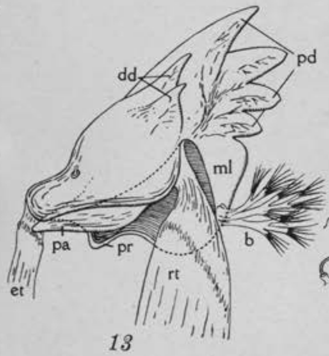

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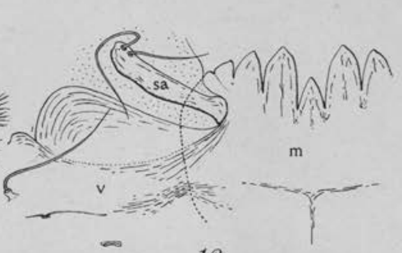

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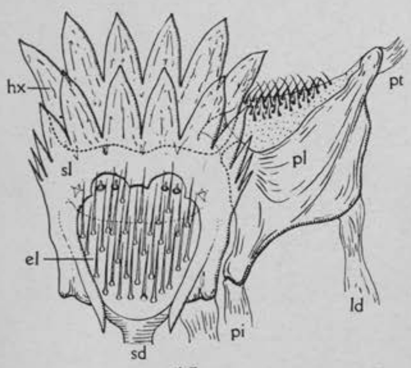

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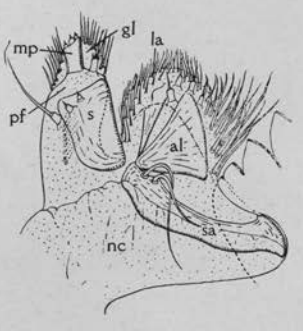

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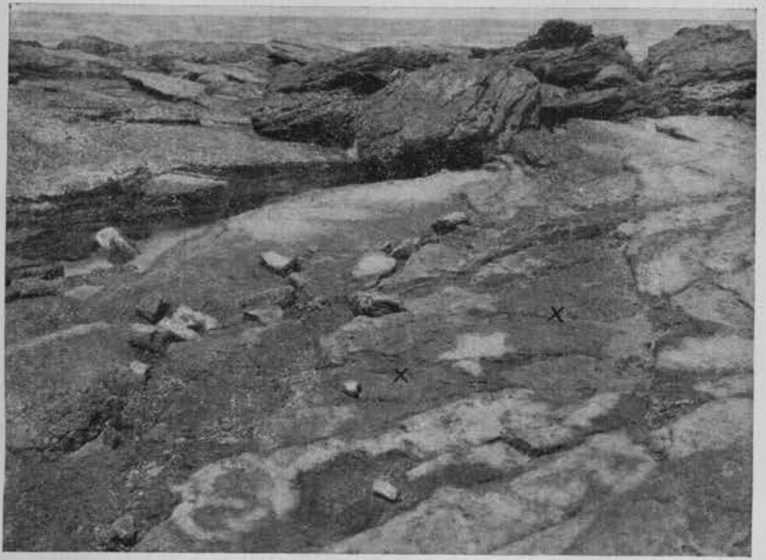
PLATE 2.



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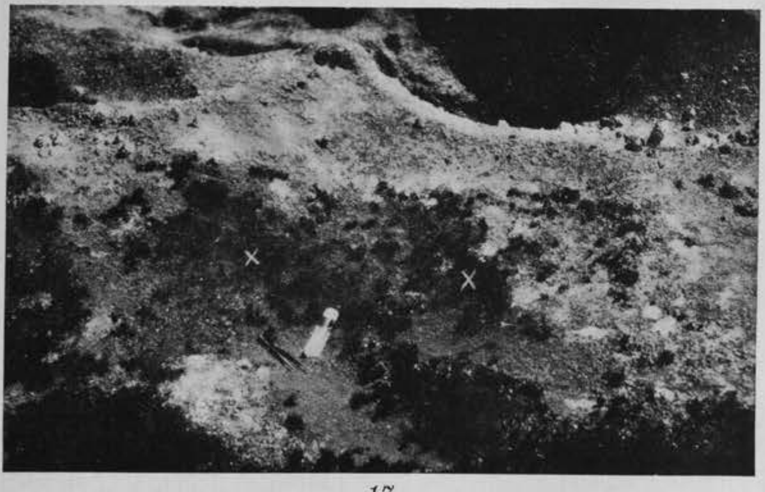

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PLATE 3.